




3 1761 11708375 8









Digitized by the Internet Archive  
in 2023 with funding from  
University of Toronto

<https://archive.org/details/31761117083758>







Lacking 1978/79, 1980/81,  
1982/83, 1984/85





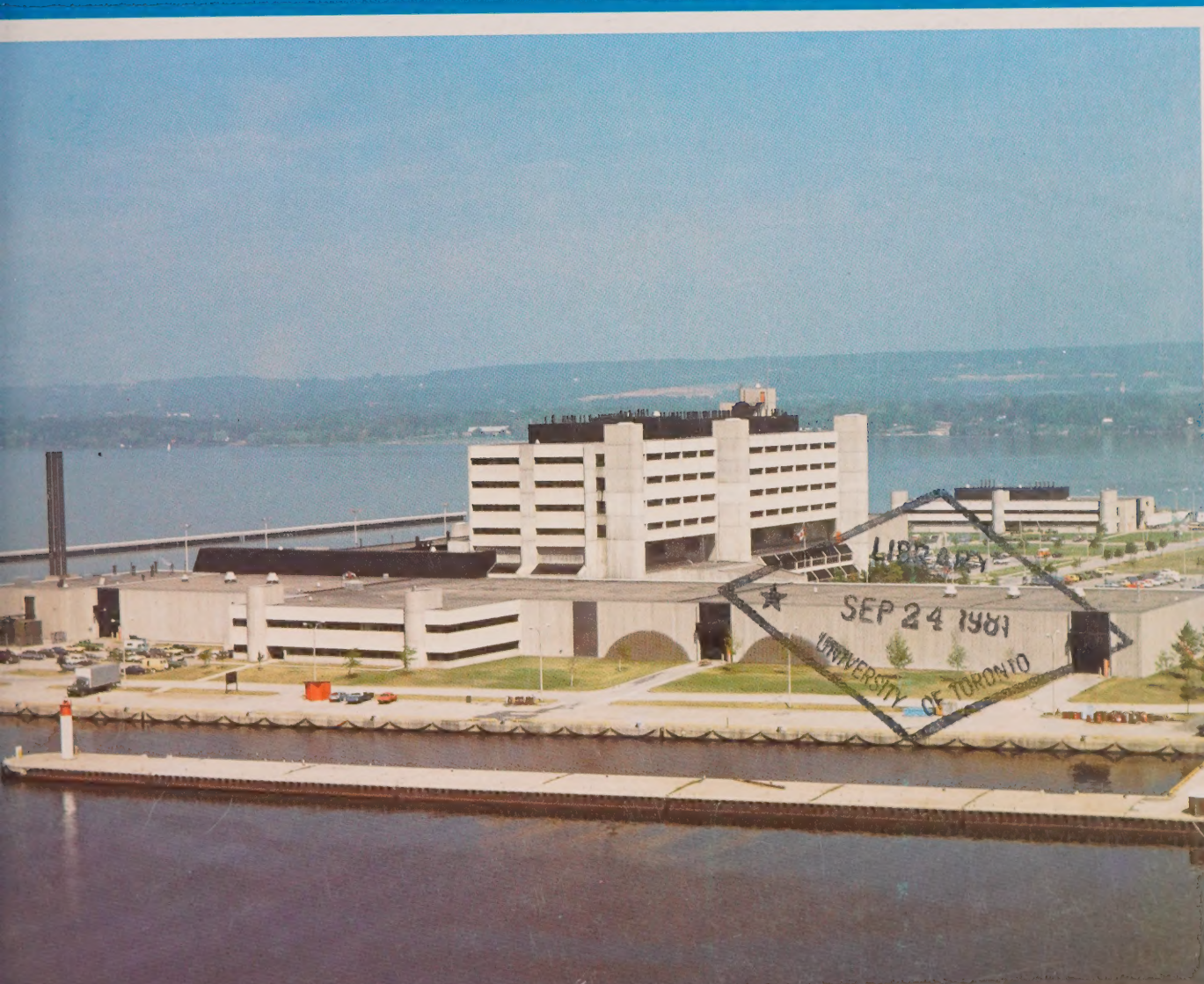


GOVERNMENT  
OF CANADA

GOUVERNEMENT  
DU CANADA

0A1  
MT64  
- C55

# National Water Research Institute



1979 - 1980 REPORT



Editor: A. S. Fraser

Assistant: D. H. Matheson

Cover Photograph: D. Fekyt

CAI  
EP

**NATIONAL WATER RESEARCH INSTITUTE**

ANNUAL REPORTS 1979/1980

National Water Research Institute  
Inland Waters Directorate  
Burlington, Ontario, Canada

Address:  
Post Office Box 5050  
Burlington, Ontario, Canada  
L7R 4A6



## **NATIONAL WATER RESEARCH INSTITUTE**

### **NOTE**

NOTICE is hereby given that mention of any product or material in this publication is not to be taken as indicating that the National Water Research Institute in any way approves, recommends or endorses any such product or material. No mention shall be made of the National Water Research Institute or of this publication in any advertising, sales promotion, reports or other written or graphic material which would indicate or imply that the National Water Research Institute approves, recommends or endorses any product or material mentioned herein, or which has as its purpose an intent to use the name of the National Water Research Institute or this publication as a means, directly or indirectly, of causing, aiding or enhancing the sale or use of any such advertised product or material.



Environment  
Canada

Environnement  
Canada

National Water Research Institute  
Inland Waters Directorate  
867 Lakeshore Road  
P. O. Box 5050  
Burlington, Ontario, Canada  
L7R 4A6

I am happy to introduce this comprehensive summary of the scientific programs of the National Water Research Institute. These programs address a wide variety of problems associated with the protection, enhancement, development and use of Canada's water resources.

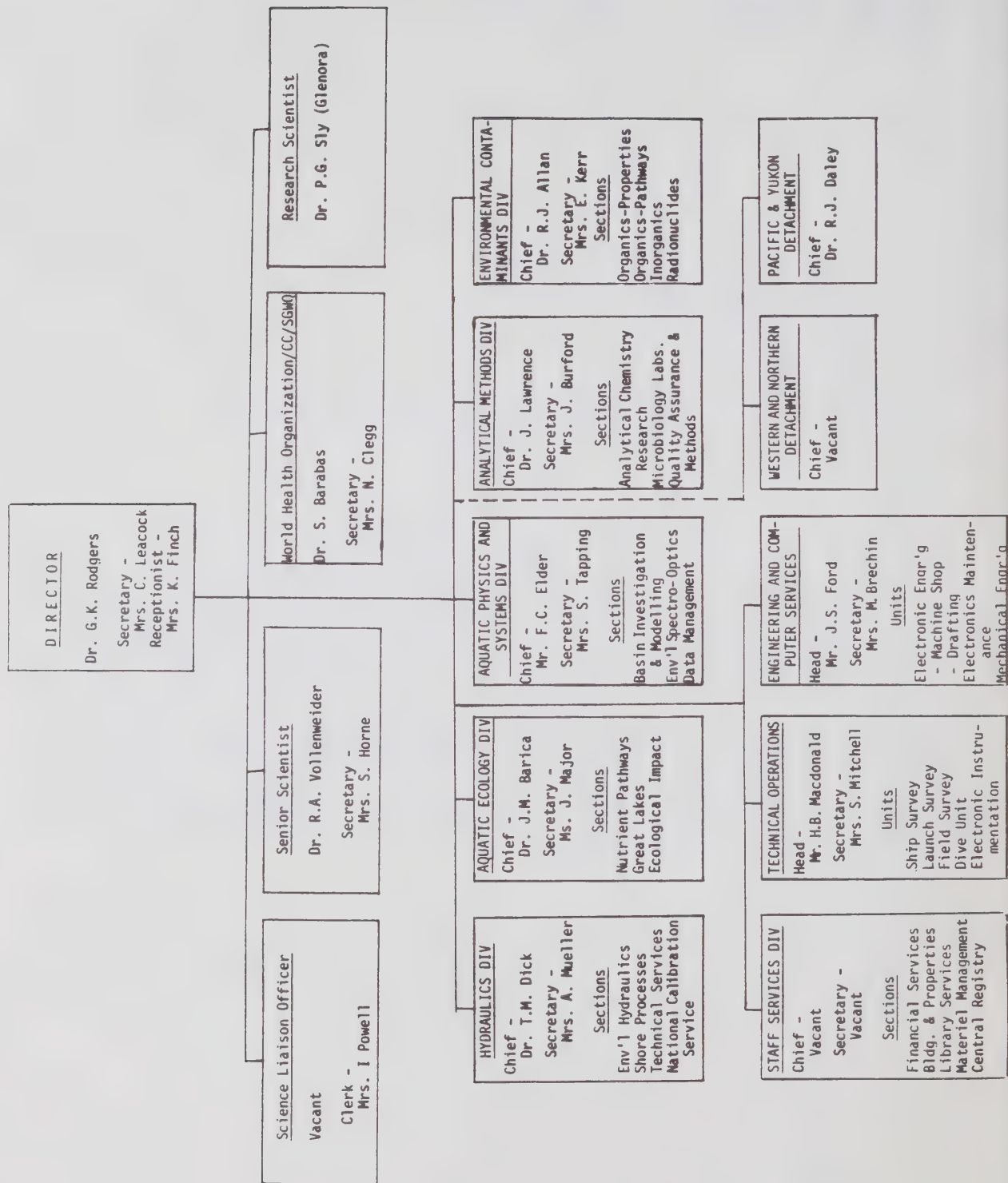
In this report the staff describe the results of the past two years work, and outline the on-going activities in the fields of environmental contaminants, aquatic physics, aquatic systems, analytical methodology, instrumentation, hydraulics and aquatic ecology. In addition, all the associated scientific services including engineering, developmental work, the technical operations program and supporting services are described.

Here we present the results of a dedicated effort to advance, apply and disseminate knowledge of considerable scientific merit and practical import that will be of interest to our clientele in federal and provincial agencies; in federal-provincial and Canada-U.S. boards; in citizen groups, academic institutions and industry; as well as the public at large.

G. K. Rodgers  
Director



# NATIONAL WATER RESEARCH INSTITUTE



## HIGHLIGHTS

The following represent some of the highlights of the 1980 activities described in more detail in the body of this report.

A review and evaluation of present modelling capability for Lake Ontario considering three aspects of water quality, i) seasonal variations, ii) long-term variations, and iii) spatial variations has been completed. This study clearly identified the strengths and weaknesses of existing water quality models and indicated the direction for further research effort.

Oxygen depletion rates in Lake Erie have been shown to change little in the past 30 years when normalized by water level and temperature.

A thermocline submodel for Lake Erie has been developed which can predict the thermocline position. This model will be of great significance in the water quality and physical process modelling work underway as the position of the thermocline is key to understanding of circulation, biological productivity, toxicant transport, nutrient cycling and oxygen depletion in Lake Erie.

Coastal zone simulation models have been developed to simulate and predict the behaviour of effluent plumes in the far-field range (0.5-2.0 km). These models can be applied to the dispersion of materials such as radionuclides, bacteria, heavy metals, and toxicants.

The analysis of steady conditions of air/water interaction has led to a better understanding of the shape of the wave frequency spectrum, and of the directional characteristics of wind waves as a function of frequency. Results permit better wave forecasting with assessments of the influence of shores on wave conditions.

A system has been built to study currents in the Littoral zone. Special drogues were designed that split in two parts after being launched. One rides the surface current, while the other follows the bottom current. After a time, the bottom part rises to the surface. The launching apparatus for the drogues travels in an all-terrain vehicle. A typical launch will project the drogue-pair fifty metres into the zone against gale force winds.

The development of *in situ* optical models which may be directly applied to water quality determination from sensors mounted below or above the water/air interface have significantly contributed to evolving the potential for determining chlorophyll *a* and suspended mineral concentrations in multi-component inland waters by spectro-optical techniques.

Research into the modelling of flow and transport in natural streams has been carried out. A numerical model which is capable of including the effects of stream curvature and changes in flow cross sections on the mixing of pollutants has been verified and found to give accurate results. The effects of ice cover on the flow and mixing properties in open channels have been investigated and early results provide methods to compute mixing and diffusion in a reliable way. Depths of flow for ice-covered flow are also obtained.

A long-term study to document and investigate the phenomena of ice jam and ice breakup has been initiated. Understanding of these phenomena is required in order to determine

the effects of ice on flooding, predict flood levels and to plan strategies for managing the ice cover on rivers. Useful lines of attack both for long-term and short-term problems are being developed.

A major undertaking in 1979 was the analysis of modern recession rates and the reconstruction of the post-glacial evolution, the detailed mapping of the nearshore sediments, and the documentation of the shoreline stratigraphy of the reach between Point-aux-Pins and Long Point on Lake Erie. This work was undertaken to provide essential information to the Department of Justice.

The CCNW main computer system was replaced with CYBER 171 which supports interactive applications.

Age profiles have been obtained for lake sediments by measuring  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  concentrations in sediment cores. These age profiles have been used to estimate dates of initial contaminant input from profiles of toxic substances determined by analysis of similar cores.

Methylation of Pb (ii) in sediments through the carbonium ( $\text{CH}_3^+$ ) mechanism has been established in chemical and biological systems. It has been found that fish can bioaccumulate  $\text{R}_4\text{Pb}$  compounds from water and analyses of fish samples have shown about 20% contain tetraalkyllead.

An analytical method was developed to detect individual polynuclear aromatic hydrocarbons at low parts per trillion level in sediments and biota.

A study of the direct sunlight photochemistry of the lampricide TFM has established that photodegradation is the main process for its decomposition in the environment. The role of singlet oxygen produced in the decomposition of organic matter where natural waters are irradiated with sunlight is being investigated.

Very promising studies have been undertaken on the assessment of fast bacterial screening tests for toxicants in water and effluents. One such test is currently undergoing first round approval for acceptance by the American Society for Testing and Materials (ASTM).

Several lake sediment reference materials were prepared as accurate reference standards for quality assurance purposes (PCB's, As and Se). This is the first time such material has been prepared and served an important need in environmental measurements.

In a study of the impact of man's activity on the limnology of bottom and near bottom conditions, fish spawning has been directly observed for the first time in 20 years on newly deposited material in the east end of Lake Ontario.

The Global Environmental Monitoring Systems (GEMS) data bank, which is part of the United Nations UNEP activities is operational.

OECD reports have been submitted on the subject of the results of the International Program on Eutrophication in which 18 countries cooperated over the last seven - eight years.



## TABLE OF CONTENTS

<b>LETTER OF TRANSMITTAL</b>	3
<b>ORGANIZATION CHART</b>	4
<b>HIGHLIGHTS</b>	5
<b>NATIONAL WATER RESEARCH INSTITUTE</b>	9
INTRODUCTION	
SENIOR SCIENTIST	
WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY	
HABITAT STUDIES	
<b>AQUATIC ECOLOGY DIVISION</b>	13
EUTROPHICATION/NUTRIENT DYNAMICS	
AQUATIC MACROPHYTES	
WETLANDS	
GEOCHEMISTRY	
PALEOENVIRONMENTAL	
<b>AQUATIC PHYSICS AND SYSTEMS DIVISION</b>	19
BASIN INVESTIGATION AND MODELLING SECTION	
SPECTRO-OPTICS AND REMOTE SENSING	
DATA MANAGEMENT SECTION	
LONG-RANGE TRANSPORT OF AIR POLLUTANTS	
<b>ANALYTICAL METHODS DIVISION</b>	29
ANALYTICAL CHEMISTRY RESEARCH SECTION	
MICROBIOLOGY LABORATORIES SECTION	
QUALITY ASSURANCE AND METHODS SECTION	
ELECTRON MICROSCOPE LABORATORY	
<b>ENVIRONMENTAL CONTAMINANTS DIVISION</b>	37
ENVIRONMENTAL RADIOACTIVITY SECTION	
TOXIC SUBSTANCES SECTION	
WATER CHEMISTRY SECTION	
<b>HYDRAULICS DIVISION</b>	43
ENVIRONMENTAL HYDRAULICS SECTION	
SHORE PROCESSES SECTION	
TECHNICAL SERVICES SECTION	
<b>ENGINEERING AND COMPUTER SUPPORT DIVISION</b>	49
APPLIED RESEARCH AND TECHNOLOGY TRANSFER	
DEVELOPMENTS AND MODIFICATIONS	
INSTALLATIONS	
CALIBRATIONS AND TEST FACILITIES IMPROVEMENT	
REGULAR SERVICES	

## **TECHNICAL OPERATIONS DIVISION**

59

SAMPLING OF LITTORAL DRIFT IN SUSPENSION  
AND LITTORAL DRIFT AND EROSION MODEL  
PORT BURWELL MONITOR AND PORT BURWELL SURVEY  
FIELD OBSERVATIONS OF BREAKING WAVES  
PORT BURWELL NEARSHORE SAND DEPOSITS  
ACID RAIN  
QUINTE/DORSET PROGRAM  
CANADIAN WILDLIFE SERVICE  
CSS LIMNOS  
CSS ADVENT  
SPECIAL PROJECTS UNIT  
DIVE UNIT SUMMARY  
RIGGING UNIT

## **STAFF SERVICES DIVISION**

65

## **REGIONAL REPORTS**

69

PACIFIC AND YUKON REGION  
WESTERN AND NORTHERN REGION

## **PUBLICATIONS**

81

SENIOR SCIENTIST  
WHO COLLABORATING CENTRE ON SURFACE  
AND GROUND WATER QUALITY  
AQUATIC ECOLOGY DIVISION  
AQUATIC PHYSICS AND SYSTEMS DIVISION  
ANALYTICAL METHODS DIVISION  
ENVIRONMENTAL CONTAMINANTS DIVISION  
HYDRAULICS DIVISION  
ENGINEERING AND COMPUTING SUPPORT DIVISION  
REGIONAL REPORTS

## **STAFF LISTS**

91





## NATIONAL WATER RESEARCH INSTITUTE

ANNUAL REPORT 1979-1980

### INTRODUCTION

This is the first annual report to be issued since 1976. Many organizational changes have taken place in the interval which have a direct bearing on the structure and the content of the report. First among these was the appointment of Dr. G. K. Kerr, formerly Associate Director for Research Programs, as Director. He succeeded Dr. A. R. LeFeuvre.

The name of the organization has been changed from the Canada Centre for Inland Waters (CCIW) Branch of the Inland Waters Directorate to the National Water Research Institute (NWRI) in the same Directorate. NWRI, which is virtually identical with the former CCIW Branch, is the largest research organization at the NWRI in Burlington, Ontario and serves the Department of the Environment as it served the former Department of Fisheries and Environment. NWRI still operates the CCIW facility for the Department as the focal point for national environmental research related to Canada's inland waters, and research and operations for water management particularly as it pertains to the Great Lakes.

The present program structure is reflected in the organizational chart which shows five research divisions - Aquatic Biology, Aquatic Physics and Systems, Analytical Methods, Environmental Contaminants, and Hydraulics Research - where previously there were three divisions.

While NWRI has experienced the substantial effects of government restraint on resource allocations exacerbated by inflation, the staff have been successful in developing leadership for studies that have drawn new subject-specific resources to the Institute, in the areas of contaminants, contracting into the Hydraulics laboratory, long-range transport of airborne pollutants (including acid rain), aquatic impact of nuclear power development, and investigations for the Great Lakes Water Quality Agreement of 1985.

The former Special Services Section of the IWD, Ontario Region is now incorporating into NWRI as the Quality Assurance and Methods Section of the Analytical Methods Division. This section has responsibility nationally for aspects of IWD laboratory control and for investigation of operational problems concerning analytical methods and their documentation.

The National Water Research Institute carries out a program of research and development designed to meet the objective of providing the necessary information and understanding of water systems for water management problems or opportunities in Canada. Building on this program of research and development, it seeks to advance, apply and disseminate scientific and engineering knowledge in the field represented by the research programs. The work includes field and laboratory research on problems of natural and human-modified aquatic regimes and contracted research. Problems investigated are of national scope, or are related to specific geographical sites referred by other agencies within or from outside the Department of the Environment. Also part of the total program is the provision of advice or information through publications, services on a consultative basis to other government agencies, advice on scientific and technical committees of the government or government supported institutions such as the International Joint Commission and the provision of scientific services such as consultations, analytical services, instrument testing, methodology documentation or inter-laboratory quality control services.

The principal establishment of NWRI is located within the Canada Centre for Inland Waters at Burlington, Ontario. Two detachments, under regional direction, are located in Winnipeg and Vancouver. One senior staff member has been assigned to the Seneca Research Station of the Ontario Ministry of Natural

Resources and a small unit working on the Long-Range Transport of Air Pollutants is based at the GLFRC in Sault Ste. Marie, Ontario. There are many other temporary field sites occupied across Canada as the need arises.

### SENIOR SCIENTIST

Dr. R. A. Vollenweider, the Senior Scientist of the National Water Research Institute, continues to give leadership in international activities. Under his chairmanship, four Regional Project Reports have been submitted to OECD as part of the OECD International Cooperative Program on Eutrophication, and a draft Synthesis Report on the total program has been prepared in collaboration with Dr. J. Kerekes from the Canadian Wildlife Service. He has further assisted the Government of Venezuela on Lake Maracaibo pollution studies, the Government of Argentina on the Salto Grande Impoundment Project and eutrophication of reservoirs. He continues to coordinate a research program between universities, governmental and private institutes, conducted for the Regional Government of Emilia-Romagna, Italy, on eutrophication of the Adriatic coastline of that region.

### WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

In October 1974, the Canada Centre for Inland Waters was designated by the World Health Organization as its Collaborating Centre on Surface and Ground Water Quality (WHO/CC).

The main function of the WHO/CC is:

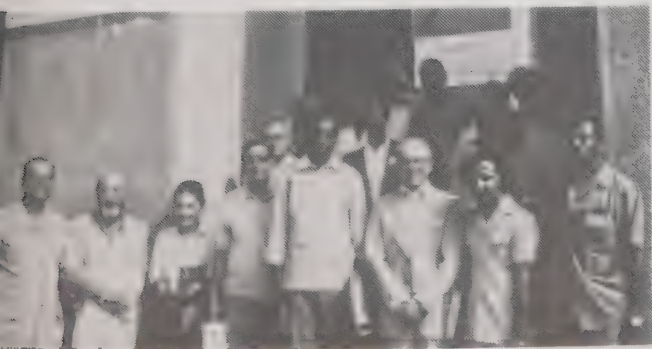
- Coordination on a world-wide basis of international technical assistance programs to the developing countries, and
- Representation of Canada's freshwater interests in international forum.

The WHO/CC had initiated in January 1976 the publication of the quarterly journal WATER QUALITY BULLETIN devoted to reviews of water management practices around the world. Furthermore, as of January 1977, the WHO/CC has assumed the responsibility of coordinating the establishment of a world-wide network of water quality monitoring stations on major rivers, lakes and aquifers around the world. The network is an integral component of the United Nations Global Environmental Monitoring System (GEMS). The main objective of this program is monitoring the long-term trends in environmental pollution.

The following is a brief review of the main activities of the WHO/CC during the year under review.

### GEMS/WATER

By the end of the year, coinciding with the end of Phase I of the GEMS/WATER project, 388 monitoring sites have been designated on major rivers, lakes and aquifers around the world as against 300 sites that were targeted for. Of the stations designated, 41 are in Africa, 80 in the Eastern Mediterranean, 58 in Europe, 60 in Southeast Asia, 46 in the Western Pacific and 103 in the Western Hemisphere. The breakdown by water body is as follows: 277 stations in rivers, 74 in lakes/reservoirs and 87 in aquifers. In conjunction with this program, two regional training courses were held of which one was in Alexandria, Egypt (for the Eastern Mediterranean Region) and one in Nagpur, India (for the Southeast Asia Region). In addition, a pilot project workshop on Analytical Quality Control (AQC) was held in Mexico City.



Some of the participants at the GEMS/WATER training course, Alexandria, Egypt, 1979.



Participants at the first GEMS/WATER Analytical Quality Control training course, Mexico City, 1979.



## Water Quality Bulletin

Four quarterly issues of the Bulletin, published in separate English and French editions, appeared each as scheduled. They were devoted to the following themes: (1) Water Management in Europe; (2) the United Nations Agencies and the Environment; (3) and (4) The Great Rivers of the World - Parts 1 and 2 respectively. In all, 30 articles were published authored or co-authored by 33 prominent scientists from the following 18 countries: Austria, Brazil, Canada, Congo, Denmark, Egypt, Finland, France, Hungary, India, Kenya, Mexico, Spain, Switzerland, Thailand, United Kingdom, U.S.A., and U.S.S.R. By the end of the year, the Bulletin was distributed in close to 150 countries or in almost all the member countries of the United Nations.

## Foreign Visitors and Consultants

During the year, study and discussion programs for 23 foreign scientists and engineers visiting CCIW were organized. The visitors came from Australia, Colombia, England, Finland, Germany (F.R.G.), India, Italy, Japan, South Africa, Sweden, Switzerland and the U.S.S.R. Of particular interest are the lengthy stays of the scientists from the U.S.S.R., Dr. N. N. Filatov (2-1/2 months); from India, A. R. Mir (1 month); and from Italy, Dr. Beccary and Dr. Ramadory (8 days). Requests for consultancies to the following countries were processed: Philippines, Malaysia, Costa Rica and Chile.

## Technical Assistance

Inquiries received from around the world, particularly from the developing countries on different aspects of problems of water management have been responded to.

## HABITAT STUDIES

### Introduction

Over the past 30 years, degradation of the Great Lakes has become of wide concern, and research and remedial measures have been strongly directed towards the goal of improved water quality. Regretably, during this same period of time, problems associated with changes in fish stocks have been treated as a largely separate issue.

However, with the submission of the 1978 Research Advisory Board report to the International Joint Commission on "The Ecosystem Approach" and the general acceptance of the ecosystem concept as evidenced in Articles I and II of the revised Great Lakes Water Quality Agreement (1978), there is now a growing appreciation of the need to "... develop programs, practices and technology necessary for a better understanding of the Great Lakes Basin ecosystem ...". This underscores the need to develop a more closely integrated approach to the management of cultural water use requirements and those of fish and wildlife.

Great Lakes management, therefore, has not achieved a sufficient objective with the establishment of a growing list of numerical water quality indices, however rigorous they may be. In appreciation of this, the Great Lakes Fisheries Commission sponsored a report on Great Lakes Ecosystems Rehabilitation and Restoration, completed in 1979. This report explicitly states that long-term management objectives in the Great Lakes should be based, not only upon the need for improved water quality, but also upon the need to rehabilitate the ecosystem. It recognizes that healthy and well-balanced fish stocks are a proper indicator of a healthy aquatic environment.

The revised Canada-Ontario Fisheries Agreement, under negotiation, reflects the principles of the strategic plan for Ontario fisheries and provides the basis for cooperative and complimentary research, surveillance and management practices which will utilize joint (Federal and Provincial) resources to best advantage.

In terms of fisheries rehabilitation, it is generally agreed that the most sensitive part of the life cycle is associated with the spawning - fry period and that spawning and nursery habitats play a major role in the ability of populations to be self-sustaining. Such habitat studies, therefore, provide a particularly important focus for cooperative environmental studies and are directly related to the needs of on-going Great Lakes management activities.

In recognition of the need for further habitat research the National Water Research Institute initiated a project entitled "Habitat Studies - Great Lakes Rehabilitation" which effectively started in 1979. This work is jointly supported by the Ontario Ministry of Natural Resources, and it is closely associated with the research programs of the Great Lakes Biology Laboratory, CCIW, and the energy and environment studies Department, Ontario Hydro (Toronto). Close working relationships have been established with the U.S. Fish and Wildlife Service and the New York Department of Environmental Conservation and field studies are being undertaken jointly with both Ontario and U.S. agencies.

Since initiating these studies, it has also become clear that spawning habitat studies are of particular importance because of the acidification of shield lakes and reduced recreational travel. These factors have the effect of increasing recreational (and commercial) fishing pressure on the lower Great Lakes.

## Study Activities

Priority has been given to the selection of lake trout and whitefish spawning habitats because: these two species are of particular importance to commercial (and recreation) fisheries; some background information is available about their behaviour; both Canadian and U.S. agencies have made lake trout introductions in Lake Ontario; and recent observations suggest that an increase in year class of whitefish may be present in Lake Ontario. On the other hand, there is evidence of a steep decline in the reproductive success of these species in Lake Simcoe.

During the first year of this study, existing information was used to select a number of potential sites where lake trout and whitefish spawnings have been historically recorded. Emphasis was given to locations in the Bay of Quinte and eastern Lake Ontario (which were once prime spawning grounds) because of logistical accessibility from the OMNR Glenora Fisheries Station (where the work is based).

Shoals were studied in the Bay of Quinte (between Trenton and Belleville, off Big Island, near Telegraph Narrows, the Long Beach and at the entrance to Hay Bay) and along the south shore of Prince Edward county and in Prince Edward Bay. Surveys were also made at Pigeon Island, Main Duck Island, and near Stony Point, New York.

The gross physical characteristics of the shoal sites were recorded by means of bottom samples, echo sounding, side scanning sonar, underwater television and underwater photographs.

The observations showed that, with few exceptions, the sites in the Bay of Quinte were now characterized by partial weed growth and significant admixtures of organic-rich mud. None were considered to be suitable for use by spawning fish (whitefish), based on comparison with earlier descriptive data. The special conditions observed at Ram Island, Hay Bay, will be discussed separately in the manuscript report on 1979-80 field activities (in preparation).

The nearshore areas of Main Duck Island and the south shore of Prince Edward county were found to be largely devoid of gravel, although coarse rubble banks frequently edged the shoreline at depths of 2.5-5 m. Some good gravel deposits were found at Pigeon Island and in Prince Edward Bay.

During the fall and early winter of 1979-80, attempts were made to observe whitefish in the Bay of Quinte and along the south shore of Prince Edward county. Storm conditions and cold weather made this very difficult and, although a few whitefish were caught (by OMNR for hatchery studies) at Point Petrie, no spawning was observed. A few whitefish were also observed just below the dam at Trenton.

Bad weather also impeded planned observations of lake trout spawning at Pigeon Island and Main Duck; but good observations were made in a cooperative field activity with the Cap Vincent Fisheries Station of NYDEC, near Stony Point, New York. These observations recorded (by means of underwater television) the first known spawning of lake trout in Lake Ontario in more than 20 years.

The Stony Point site proved to be exceptionally interesting because the local gravel deposit (which formed the spawning site) has only recently formed, adjacent to a new shoreline construction, and could not have been used by indigenous lake trout stocks prior to the late 1950's.

Particular attention has been given to the substrate stability at the Stony Point site and a series of resurveys have been initiated to look at the changes in the gravel beach and slope, over an extended period in response to seasonal storm and ice effects.

In addition, sites at Ram Island and Point Traverse were instrumented with self-recording thermistors to define the short-term temperature fluctuations in nearshore waters during the fall-to-winter cooling period and spring warming.

Studies are also underway to define the spatial shift of thermal isotherm conditions in Lake Ontario based upon a synthesis of existing CCIW temperature data and municipal water intake (temperature) records.

Ice-cover data is also being utilized to discern year to year, and local variations of nearshore ice cover in the eastern basin of Lake Ontario.

Because of the importance of the substrate surface, during the initial stages of egg entrapment, particular attention has been given to the description of bedrock micro relief and gravel/rubble matrix; and a survey of regional joint patterns and glacial scour has been made to obtain supplementary information. A preliminary experiment on egg adhesion to different forms of substrate was also carried out.

A manuscript report providing examples of observations, the significance of various environmental factors on potential spawning success, and a discussion of observational techniques (including a comparison between 100 KH<sub>3</sub> and 500 KH<sub>3</sub> side scan sonar, and the operation of TROV I as a mobile platform) is in preparation and will provide more detailed information.





## **AQUATIC ECOLOGY DIVISION**





The Aquatic Ecology Division undertakes basic and applied research of processes which occur in lake waters and sediments. Research is strongly focused upon problems and concerns of water management and the Division's staff are actively involved in advisory and consultative capacities on numerous committees, forces and studies.

Major activities are:

**Eutrophication/Nutrient Dynamics:** biological response to nutrients; understanding the functions of aquatic ecosystems; chemical composition and the role of colloidal and dissolved organic substances; lake restoration techniques; oxygen depletion studies.

**Wetlands:** understanding the complexities of this environmentally sensitive ecosystem; impact of cultural development on wetlands.

**Geochemistry:** sediment/water interaction studies; characterization and distribution of sediments; geochemical cycles.

**Paleoenvironmental:** identification of trends in the trophic status of lakes which may be related to natural aging, climatic change, or cultural impact.

**Aquatic Macrophytes:** impact of aquatic macrophytes on lake ecosystems and development of control methods with minimal environmental drawbacks.

The work of the Division is carried out in three sections:

Nutrient Dynamics Section  
Geology Section  
Paleoenvironmental Section

The overall objectives of the Nutrient Dynamics Section are to quantitatively understand 1) the contribution of various nutrients (C, N, P, Fe, O) to algal metabolism and growth, and 2) the effect of epilimnetic algal production and organic loadings on hypolimnetic oxygen depletion. Emphasis is placed on understanding the function of microorganisms in the aquatic environment and gaining knowledge of their physiological processes.

The Geology Section conducts a wide variety of projects on unconsolidated geological materials, their interactions with freshwater systems, and their implications for water management. Studies related to geochemistry, sediment dating, lake acidification, geophysics and wetland studies are all included within the scope of this Section.

The current research of the Paleoenvironmental Section is concentrated on evaluating the data base compiled over the past several years. Interpretive models for predicting the impact of human intervention on nature will be made from autecological information.

## EUTROPHICATION/NUTRIENT DYNAMICS

Nutrient dynamics research is necessary to understand the eutrophication process. Current research at NWRI stresses the need for effective water quality standards associated with nutrient loadings and the resulting biological response. A wide range of lake types from oligotrophic to hypertrophic have been chosen as sites to study the complex interrelated processes of nutrient availability and uptake, algal growth and decomposition, sedimentation, nutrient regeneration, "dissolved" organic substances, zooplankton grazing, and lake restoration techniques.

During the past year, considerable effort has been expended to identify and quantitate fundamental phytoplankton - nutrient relationships. Research on phosphorus and nitrogen dynamics (in Lake Erie; Jacks Lake; Lake St. George; Kootenay Lake, B. C.) has shown that phytoplankton photosynthesis was depressed under nutrient limited conditions. Although the observation that algae opt for expending energy for nutrient uptake rather than fixing carbon they do not require is reasonable it contradicts the standard  $^{14}\text{C}$ -bioassay technique used to determine limiting nutrients. A study comparing phosphorus uptake by chemical and

radiolabelled  $^{32}\text{PO}_4^{3-}$  methodologies has shown that, at low levels of added phosphate, the release of cellular phosphate causes the chemical values to be lower than the influx measurement using the radioisotope. In the extreme case of zero added phosphate, influx and efflux are equal and chemical uptake is zero. Exchange at this point is very rapid. Small (<5 micron diameter) algae and bacteria in lakes differ from larger phytoplankton in nutrient uptake patterns. The small organisms appear to be able to utilize nutrients at very low concentrations (a few micrograms/l or less). The larger algae, however, seem to be dependent upon brief periodic encounters with high concentrations of phosphate (at least 5-10  $\mu\text{g/l}$ ). This research has relevance to the problems of what causes certain species of nuisance algae to predominate in some lakes, but not in others. The ability of small algae to take up low concentrations of phosphate at a high rate has led to the use of continuous culture of *Anacystis nidulans* for phosphorus bioassays. The cells respond only to the fraction of phosphorus in a natural water sample which is bioavailable. The uptake rate, measured by  $^{32}\text{PO}_4^{3-}$  techniques, can be used to estimate the amount of bioavailable-P. An interpretation of numerous measurements of two forms of phosphorus (total and soluble reactive) in Lake Ontario from 1969 to 1979 has shown that progress in the desired direction of a lower phosphorus content is being rapidly achieved in recent years.

Research on the nitrogen cycle in lakes has continued. The factors which influence the rate of nitrogen loss from lakes by the conversion of biologically available nitrogen to nitrogen gas and nitrous oxide have been identified. Ammonia uptake velocities in Lake Erie have been measured and during the June-September period were 0.17 - 0.35  $\mu\text{g N/l/hr}$ . Turnover times for the ammonia pool were 24-40 hr. About half of the total regeneration of ammonia in the water column was caused by zooplankton grazing and excretion.

The stable isotope  $^{15}\text{N}$  methodology for measuring ammonia and nitrate uptake rates was originally established in our laboratory and we have been involved in technology transfer of this technique to other laboratories in Canada and the United States.

Preliminary characterizations of the colloidal and dissolved forms of naturally-occurring organic substances in lake water has continued. The research advanced slowly on three elemental fronts: dissolved organic phosphorus (DOP), nitrogen (DON) and carbon (DOC). Only 5-10 percent of the DON can be accounted for by analysis of the combined amino acids (estimates peptide and protein content). Techniques for isolation and purification of high molecular weight colloidal materials have been developed. The material consists of fibrillar polysaccharides with uronic acid residues. The component sugars have been identified for several lakes. The characterization of colloidal phosphorus compounds by specific enzymatic hydrolysis is well underway.

Simple reliable estimates of living biomass in lakes continue to be a goal and chlorophyll *a* estimates have been improved by a modified dimethyl sulfoxide extraction procedure and the adenosine triphosphate (ATP) extraction procedure has been greatly improved by an alkaline treatment of samples.

The importance of iron chelators on blue-green algal dominance in certain lakes was further studied in Yellow Lake, B. C. These chelators (siderochromes) are utilized very rapidly when iron is in short supply. In this particular lake, iron seems to be controlling algal productivity. Massive algal blooms developed when iron was released from the sediments.

Mossbauer studies have continued to identify the forms of iron in the sediments. This is a prerequisite to a better appreciation of iron-phosphate complexation. In surficial Lake Ontario (deep hole) sediments, the  $\text{Fe}(\text{OH})_3$  content can be used to calculate the adsorbed phosphate concentration of  $0.22 \pm 0.15 \text{ g m}^{-2}$ . This is 10-50 percent of the nonapatite inorganic phosphorus. In other lakes, we have shown the presence of amorphous refractory ferric compounds which are speculated to be ferric aluminosilicates which fix elevated levels of phosphorus.

Lake restoration by the hypolimnetic aeration technique has met with varying degrees of success. The consequence of aeration either by hypolimnetic aeration or by a simple subsurface aerator is being investigated.

During the summer of 1979 (April to October), eight cruises in the central and eastern basins of Lake Erie were made. Sedimenting material was collected in traps placed near the bottom and just under the thermocline. Primary production, respiration and water quality parameters were measured at each station. Primary production and respiration in the water column were almost identical, meaning that the amount of biodegradable organic material available to cause oxygen depletion was small. Seston concentrations (dry weight, chlorophyll, POC) were as high or higher in water near the bottom as in the surface water. The photosynthetic capacity of the water near the bottom was similar to that of surface water. Primary production in the central hypolimnion, although measurable, did not seem to affect the oxygen depletion. Sediment traps caught falling organic matter at a rate close to that required to sustain the oxygen depletion. Chemical analyses of sediments and sedimenting material are underway and production/respiration data are being analyzed.

Oxygen depletion in Lake Erie has been observed for many years. When factors such as water level and temperature were taken into account, it has been shown that there has been little change in the oxygen depletion rate in the last 30 years (Figure 1). The shallow central part of Lake Erie is the area most likely to develop low oxygen conditions near the bottom in late summer. Since any extension of low oxygen conditions is undesirable, continuing research will provide an understanding of the probable response of the oxygen depletion to change in nutrient loading.

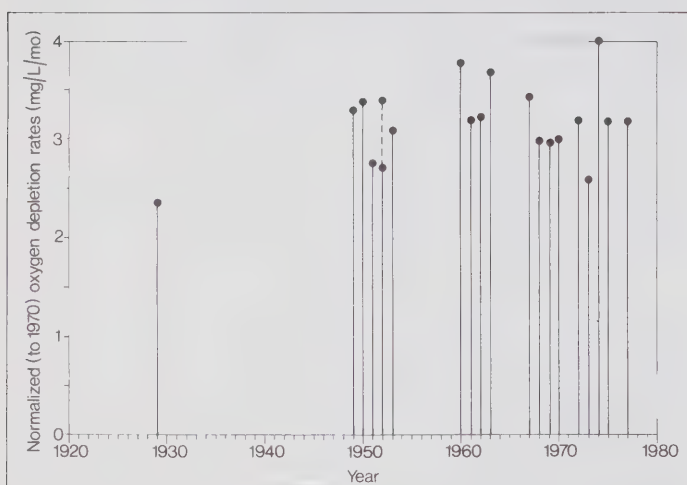


Figure 1 Lake Erie hypolimnion oxygen depletion rates, normalized for the effects of different thickness and temperature.

The 1977 and 1978 Lake Erie hypolimnetic oxygen and temperature data have been looked at in detail, and the oxygen uptake rates for each stratified interval have been calculated.

The oxygen uptake rates have been calculated using two different approaches: the first approach uses the results from the computer program SURVEY 8 together with the MESOLIMNION-EXCHANGE-MODEL for each of the two basins; the second approach uses a specifically defined homogeneous area for each basin, where oxygen uptake rates are calculated using simple oxygen concentrations for each station in that area. These uptake rates have been adjusted for temperature difference, and for hypolimnetic reoxygenation using the survey interval temperature increase. The unadjusted uptake rates for 1977 and 1978 central basin were  $3.42 \text{ gm/m}^3/\text{month}$  and  $2.82 \text{ gm/m}^3/\text{month}$  respectively, while the adjusted rates were  $3.19 \text{ gm/m}^3/\text{month}$  for 1977 and 1978.

The results of the vertical fluxes of organic carbon study in the eastern basin of Lake Erie indicated no significant difference between the settling velocity of the particulate organic carbon (POC) found in the epilimnion and hypolimnion. The seasonal average settling velocity for the POC measure was nearly  $1.0 \text{ m/day}$ . The mean flux for the two strata was also very similar. Fractionation experiments indicated that the particles less than  $20 \text{ }\mu\text{m}$  had the lowest settling velocity but contributed the largest percent of the total flux. The particles larger than  $20 \text{ }\mu\text{m}$ ,  $45\text{--}100 \text{ }\mu\text{m}$ , and greater than  $100 \text{ }\mu\text{m}$  showed increasing settling velocities with increasing size but all three fractions contributed nearly equally to the total flux.

The objective of this project was to evaluate and improve the environmental impact and effectiveness of control technologies.

Mechanical harvesting has been criticized as a short-term control but properly monitored harvesting programs have observed long-term impacts in 12 of 13 experiments. In some lakes the nuisance aquatic plant (milfoil) has dramatically declined. The impact of twenty different harvesting strategies are observed to determine which is the most effective. An attempt is being made also to isolate the causal factor behind the decline of milfoil in Chemung and Buckhorn Lakes. Recent evidence suggests that sediment nutrient limitations as a result of harvesting impact are responsible for the decline (Figure 2).

Chemical control of milfoil with 2,4-D has an unpredictable environmental impact because we do not fully understand the dynamics of the herbicide. Some monitoring programs have observed significant concentrations in the water for 70 days and in the sediment for 12 months. The impact of 2,4-D on community structure and productivity and the persistence and degradation of 2,4-D and its metabolites are being investigated.

Several species of aquatic plants are a nuisance in the southern United States and were banned for importation into Canada. The survival potential of the banned plants in our Canadian climate is being investigated. Preliminary results indicate that all milfoil species, *Hydrilla* and *Trapa* will survive. *Elodea densa* will probably not survive but, if it did survive, it would not become a nuisance. *Alternanthera* and *Salvinia* will not survive in Canada.

The impact of milfoil nutrient demand on interstitial chemistry is being studied to determine if a limiting nutrient situation exists and also to develop a predictive model of sediment chemistry. The use of a plastic sheet material laid on the lake bottom is being investigated as a means of control of the growth of nuisance aquatic macrophytes in sensitive shoreline areas.

The intimate ecological relationship between the nuisance submerged macrophyte, *Myriophyllum spicatum*, and its nitrogen-fixing blue-green epiphyte, *Gloetrichia*, have been studied in Buckhorn Lake, Ontario and Lake Memphremagog, Quebec. During the late summer, the *Myriophyllum*, which is rooted in the sediments of shallow waters, appears incapable of obtaining enough nitrogen for continued growth. Under these conditions,  $\text{N}_2$ -fixing algae which colonize the leaves and stems of the plant may be able to supply some nitrogen. This hypothesis is being tested on plants in the lakes using  $^{15}\text{N-N}_2$  and  $^{14}\text{C-CO}_2$  isotopes. Very high rates of  $\text{N}_2$ -fixation by the epiphyte have been observed and there also appears to be a reverse transfer of carbon from the plant to the epiphyte. The elucidation of this relationship continues along with work on other aspects of aquatic macrophyte overgrowth.

## WETLANDS

The coastal wetlands in the Hudson Bay lowlands were investigated to determine their sensitivity to future possible development. During July 1979 field trips were made to Attawapiskat and a field camp in the tundra near Cape Henrietta-Maria. Intensive studies were made on salt marsh development and vegetation ecology between the mouth of the Ekwan river and the Brant River west of the Cape on the shore of Hudson Bay. A total of 17 transects were run, 14 of which have complete studies of sedimentology, pedology, vegetation composition and abundance, and sedimentary invertebrates. Analysis of this data has recently started. Sediments were collected to determine accretion rates in tidal flats and marshes and weathering studies in cooperation with the University of Guelph have also started.

A primary productivity study was completed on a subarctic salt marsh located at North Point on the southwestern shore of James Bay, Ontario. Biomasses of individual plant species and litter weights were obtained on four occasions from mid-June to late August 1979 in six salt marsh zones which ranged from the lower intertidal flats dominated by the grass *Puccinellia phryganodes* to the willow thickets dominated by *Juncus balticus*. The above-ground biomass reached its peak in almost all zones by early August and ranged from  $199.3\text{--}240.4 \text{ g/m}^2$  dry weight. Litter accumulated in all except the two lower zones which were subject to tidal flooding. The highest zone where *Juncus balticus* occurred had



highest litter mass, 572.8 g/m<sup>2</sup> dry weight while the lowest 7 g/m<sup>2</sup> occurred in the lowest zone. Estimates of the net aerial primary productivity ran from a low of 119.3 g/m<sup>2</sup> in the upper salt marsh to 384.0 g/m<sup>2</sup> in the zone dominated by *Juncus balticus*. The net marsh net aerial primary productivity was 227.7 g/m<sup>2</sup>, low in comparison with other global salt marsh data. The 1977 biomass was significantly lower than similar data in 1976, probably because of a cooler summer.

## GEOCHEMISTRY

As with other areas of research at NWRI, environmental geochemistry studies are national in scope and complement the work of other federal and provincial agencies in respect to the development of more effective water quality standards and methods for water quality management.

Twenty-two lakes in Sudbury and surrounding areas were surveyed during the summer of 1979. Besides the background data such as pH, temperature, conductivity, Secchi-depth, and sediment texture, the suspended particulates were obtained by means of a low-through centrifuge. Trace metal contents of the suspended particulates were determined following the usual wet digestion, while the physical characteristics and chemical composition of

individual grains were evaluated using the scanning electron microscope. From the concentrations in unfiltered samples, the fraction of each trace metal associated with the particulate material can be calculated. As expected, the nickel contents of suspended particulates were very high, averaging 1500 µg/g in Ramsay Lake, over 2000 µg/g in both McFarlane and Vermillion Lakes, 580 µg/g in Windy Lake and 620 µg/g in Wavey Lake. The copper contents of the particulates ranged from the average of 570 µg/g (Ramsay Lake) to about 50 µg/g (Windy and Nelson Lakes); the zinc values ranged from over 900 µg/g (McFarlane Lake) to about 300 µg/g (Nelson Lake); the highest cobalt content (about 90 µg/g average) was recorded in Vermillion Lake. The total metal concentrations in the water become occasionally quite high; ranges in values observed include 1-600 µg/l for copper, 5-500 µg/l for nickel, and 2-100 µg/l for zinc. The suspended particles generally account for much less than 10 percent of the metals in the water. This implies that the metals are not only elevated in concentration but also occur in a form readily available to the aquatic fauna and flora.

Sediments act as the ultimate sink for many persistent contaminants, both organic and inorganic. In this way the sediments produce a record of varying contamination. A Bank of Great Lakes sediments, fulfilling in part the requirements under Annex 12 of the Great Lakes Water Quality Agreement of 1978, is being built. This

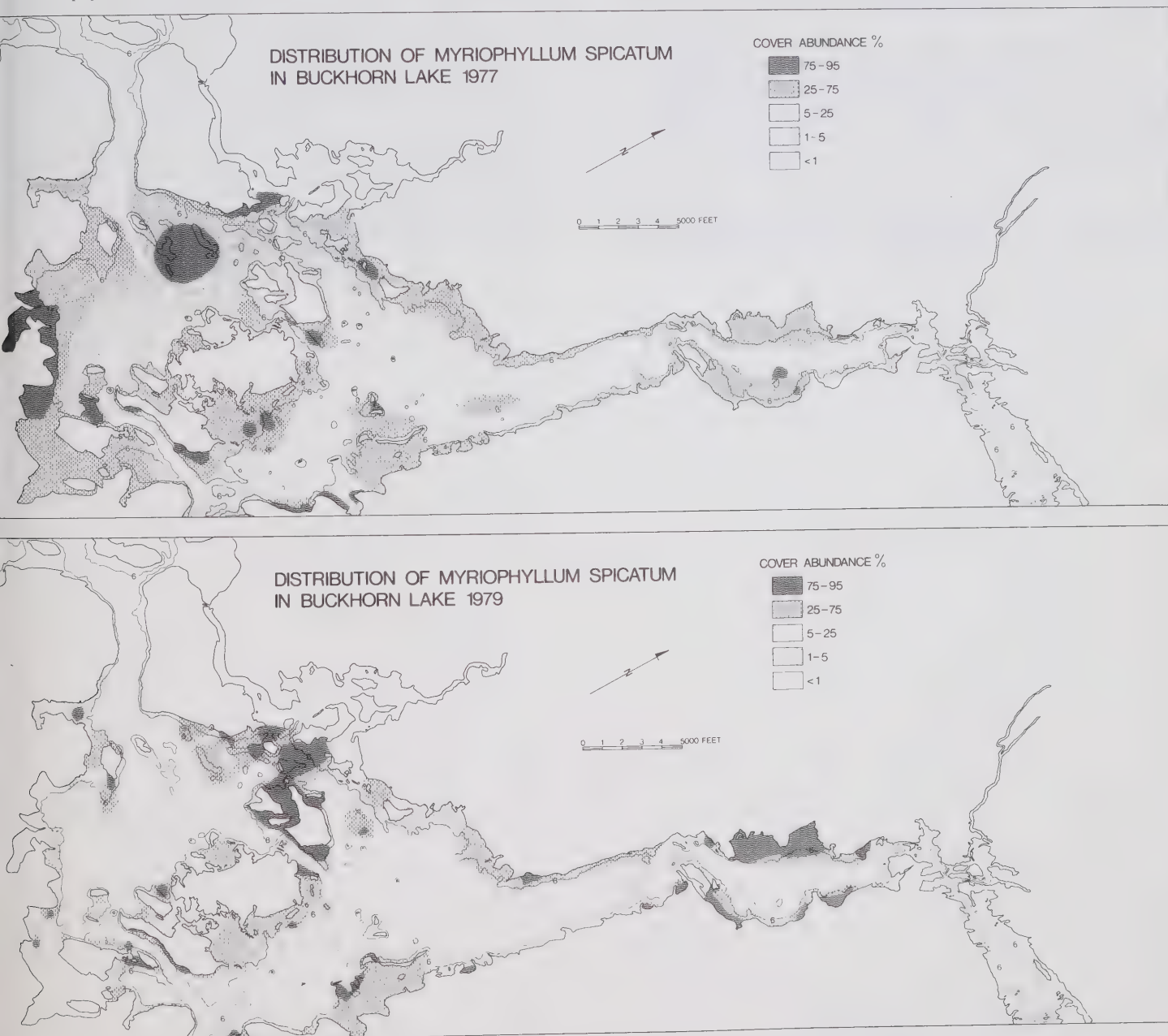


Figure 2 Comparison of milfoil abundance in Buckhorn Lake in 1977 (upper) and 1979 (lower). Note the decline in the south end of the lake where extensive harvesting occurred from 1976 to 1978.

Sediment Bank will serve as a source of baseline material from which to reference future contamination problems and as an integral part of an early warning system to aid in understanding trends in contaminant loading.

Fiscal year 1979/80 was the initial year of this study operated jointly with the Environmental Contaminants Division. A long-term preservation study was initiated in November 1979 with the collection of bulk samples of surficial sediment from two locations in Lake Ontario. Preliminary results indicate that 1) losses of organochlorines and PCB's due to freeze-drying are negligible within experimental error, 2) DDT and metabolites show about 30 percent loss on frozen storage for two months, but hexachlorobenzene and PCB's do not decrease in concentration over the same period, and 3) it is preferable to homogenize freeze-dried rather than wet samples.

A suitable facility has been built for storage of the bulk sediment samples which will comprise the Sediment Bank. Existing sediment samples collected for previous CCIW studies have been inventoried, and appropriate samples may be selected from these to be included in the Bank. A number of logistical details were worked out to prepare for the large-scale sampling of all the Great Lakes commencing with Lake Huron in 1980.

The focus of present organic geochemical studies has been primarily developmental during the latter part of the fiscal year 1979/80. Laboratory facilities were upgraded and technical personnel trained for analysis of naturally-occurring organics. Methodologies are being developed for the isolation and analysis of lipids such as aliphatic and aromatic hydrocarbons, fatty acids, alcohols, and sterols. Gas chromatography is the primary analytical technique in these studies.

Efforts are currently underway to apply these methodologies to problems of geochemical and environmental significance. This organic geochemical approach is being utilized to study

sediments from lakes in the Sudbury region with the aim of recording and predicting the effects of lake acidification on carbon cycling. Holocene sediments from the Great Lakes will also be studied by this approach. We will focus on understanding those processes which control the deposition and diagenesis of sedimentary organic matter. Particular emphasis will be placed on the relationships between humic matter and its precursor materials and on anthropogenic influences as recorded by sedimentary organic constituents.

Geophysical studies have also been undertaken in the Geology Section. The Acoustic Images of Underwater Structures study was undertaken in response to a request from Parks Canada (DINA) and in cooperation with the Royal Ontario Museum. Its aim is to develop, refine and improve acoustic methods and techniques using existing transducer technology in order to provide new systems capable of elucidating underwater structures in deep and turbid water, where visual methods cannot be applied. Digitizing of all the analogue data has been completed by the Jet Propulsion Laboratory in Pasadena, California. First pass images have been reviewed and a filter and enhancement scheme selected for the further processing of the digital data.

#### PALEOENVIRONMENTAL

This area of research is national in scope; it addresses the extent and ratio of environmental change and considers their significance. Special emphasis is placed upon the separation of cultural influences from the natural background conditions during the past 100-300 years. An exploratory analysis of pollen data in sediment core from Echo Lake in the Qu'Appelle Valley, Saskatchewan has been performed. This analysis led to an improved procedure that allows statistical inference to be made about the point of change, having eliminated other parameters, where these parameters represent features of the sequence of observations other than the point of change.

## **AQUATIC PHYSICS AND SYSTEMS DIVISION**





## INTRODUCTION

The Aquatic Physics and Systems Division of NWRI conducts a program of research incorporating balances of experimental measurements and numerical, theoretical analysis. Emphasis is placed on physical understanding of the dynamics of inland waters through investigation of the circulation and mixing and diffusion processes of lakes as these factors interrelate with and control the distribution of dissolved or suspended materials such as biological nutrients, contaminants or radionuclides. Optical characteristics of natural waters are investigated as related to applications of spectro-optical characterization from in-situ, airborne or satellite borne sensors. Numerical systems models are developed employing both deterministic and stochastic analysis to simulate both physical or biochemical processes in lakes, streams or other components of the aquatic regime. In close support of the research program of this Division and of other research units of CCIW, a data base management section maintains archives of environmental data and provides assistance in scientific computer programming. This data base management function is a direct contribution to large scale environmental surveillance such as the IJC Great Lakes Water Quality program and the Global Water Quality Monitoring Program.

The research of the Division is organized into three Sections and a special task contribution to the Interdepartmental Long-Range Transport of Air Pollutants program. These are:

- (i) Basin investigation and modelling
- (ii) Spectro-optics and remote-sensing
- (iii) Data management
- (iv) Long-range transport of air pollutants task.

## BASIN INVESTIGATION AND MODELLING SECTION

The research activities of the Basin Investigation and Modelling Section can be broadly grouped under two major headings. They are: 1) Physical Limnology of Lakes and Reservoirs; and 2) Water Quality and Aquatic Ecosystems Modelling.

### Physical Limnology of Lakes and Reservoirs

The general objective of the Physical Limnology Program is to describe and to quantify through field measurements, analysis, and theory, the water movements which take place in lakes and reservoirs and which affect the quality of the aquatic environment. There are a number of circumstances in which water movements and water quality are linked - such as dispersion of effluents from a sewage outfall in coastal waters or the transfer of nutrients to the euphotic zone from deep water. Such physical research programs in situations where there are direct linkages between water movement and water quality have been carried out in recent years and are described in this report.

### Lake Erie Physical Limnology Experiment

The central basin of Lake Erie, with its tendency towards late summer anoxia of the bottom water, has been the object of much study and concern. The oxygen consumption in the hypolimnion is related to the external loading to the lake, to the sediment properties, and certainly to the physical processes which distribute materials both horizontally and vertically through the basin. These processes may be grouped into three basic study areas of vital importance to water quality management. First, there is the question of the extent to which the hypolimnion of the central basin is supplied with water from the relatively oxygen-rich hypolimnion of the eastern basin. Prevailing winds cause an eastward drift of surface water which must be compensated by a subsurface westward return flow. The return flow can involve both epilimnion and hypolimnion water, the relative distribution depending among other things on turbulent entrainment across a stable thermocline. The second study area concerns the mechanisms by which materials introduced at the shoreline are transported and mixed into the offshore regions of the basin. Horizontal mixing is attenuated near the shoreline in comparison with the vigour of the offshore processes, so that substantial onshore/offshore concentration gradients are frequently encountered. Moreover, much of the exchange is thought to be accomplished during episodes of upwelling and downwelling which in turn are related to the response of a closed basin to wind forcing. The significance of these processes regarding

the pathways of a biologically reactive agent depends on the ratio of the decay or reaction time scale of the agent to the flushing time scale of the coastal region. A small ratio suggests the division of the basin, as far as the concentrations of this agent are concerned, into an onshore and an offshore zone, whereas a large ratio suggests rather than the basin may be viewed as a homogeneous whole. Finally, the third study area focuses on the process of vertical turbulent transport in a stratified fluid and aims therefore at quantifying the vertical fluxes to and from the hypolimnion in mid-basin.

In 1977 an array of current meters was installed in the general area of the Pennsylvania Ridge, a feature striking NW/SE across Lake Erie, with additional instruments being located in both the middle of the eastern basin and in the middle of the central basin. The array was maintained in place from May 1977 until the end of October 1977, thus spanning the entire stratification period. Data from this array, together with temperature profiles taken during the ship cruises of that year, have been used to prepare estimates of the flux of hypolimnion water between the two basins. An attempt has been made to establish, in addition to the mean flux, estimates of the flux variance about the mean and its sensitivity to errors in the estimates of the mean flow speed and interface depth (Figure 1). This work is reported in a recent issue of the Journal of Great Lakes Research (Boyce *et al.*, 1980).

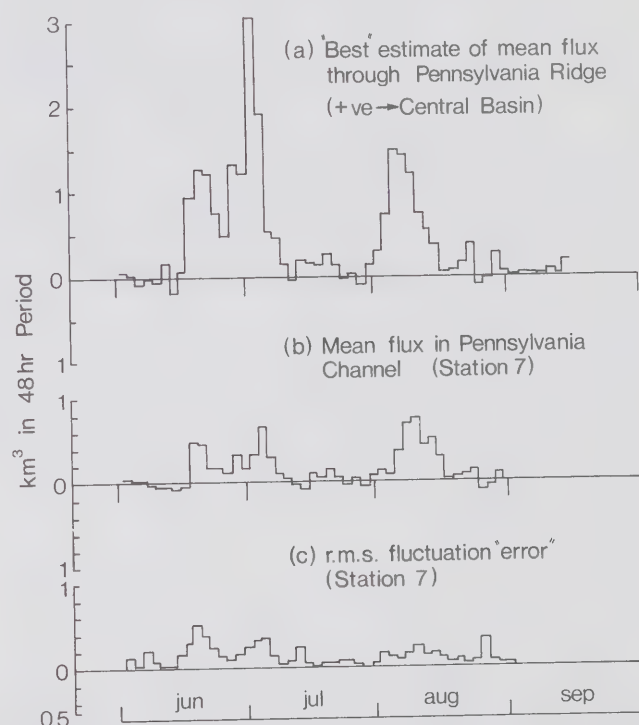


Figure 1 The upper panel represents 48-hour averages of the hypolimnion flux estimated from current meter data. The lower panel is a simulation of the hypolimnion flow based on a two-layer open-channel flow model.

The designation of 1978 and 1979 as years of intensified field effort by the Surveillance Subcommittee of the IJC provided an opportunity to work in several study areas outlined above as a contribution towards the surveillance goals. In 1978 we repeated the 1977 experiment aimed at measuring the eastern-central basin exchanges. This data was needed to support nutrient budget measurements in the central basin and serves also as a data base from which to model the exchange flows. More extensive measurements of the temperature and the surface currents were made. A modelling study, developed under contract with McMaster University, has demonstrated that the main features of this exchange flow can be simulated using straightforward concepts from the open channel hydraulics of two-layered flow (Figure 2).

In 1979 we undertook a joint measurement program with our U.S. counterparts at the Great Lakes Environmental Research Laboratory in Ann Arbor, Michigan. The U.S. experiment aimed at providing a picture of the large scale circulation in the entire lake;

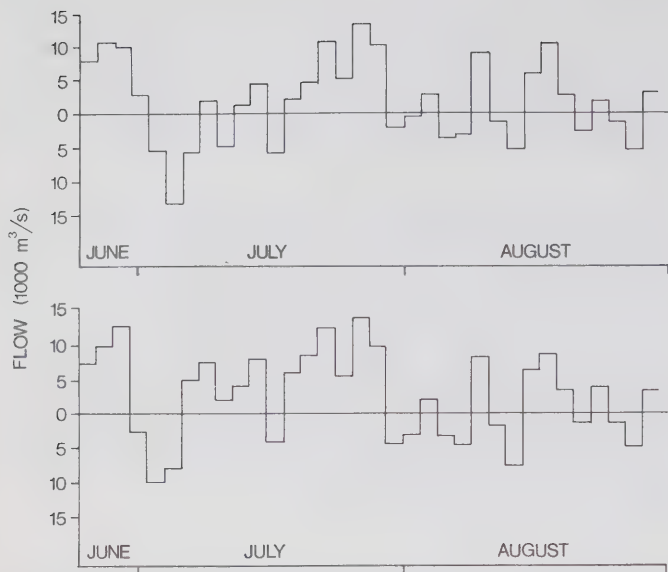


Figure 2 Estimates of hypolimnion flow for successive 48-hour periods between the central and eastern basins of Lake Erie during the 1977 stratified season.

an array of current meters and thermistor chains was widely spaced in all three basins. Building on the U.S. network, NWRI established more closely spaced arrays of current meters, thermistor chains, and meteorological buoys at four locations. Three of these were coastal sites, the first on the north shore of the eastern basin near Nanticoke, the second, on the southwest shore of the central basin, off Cleveland, and the third, along the north shore of the central basin. These arrays were designed to give information on the onshore/offshore exchanges of water. The fourth site was located in the middle of the central basin northwest of Cleveland. Here, in mid-basin, the goals were to document the horizontal water motions at scales much less than those resolvable by the U.S. network, to study the physical process of vertical mixing, and to provide supporting physical data for biochemical experiments conducted at the mid-basin sites. These last experiments were conducted from the research ship LIMNOS while at anchor in mid-basin. In July, August, and September, the LIMNOS kept station in the centre of the mid-lake array for periods of ten days at a time. Physical measurements of water temperatures, optical parameters, meteorological parameters, wave heights, drogus drift, internal waves, and bottom currents were made in conjunction with sampling and analysis for dissolved oxygen, nutrients, suspended sediments, and other materials.

During the July-September period, the launch ADVENT was stationed in Eriean, Ontario. She was used to run local small scale surveys of temperature and dissolved oxygen on the north shore of the central basin, and at the mid-lake site. The nearshore surveys revealed a persistent upwelling feature on the north shore of the basin, a typical example of which is shown in Figure 3. This process may have an important bearing on the oxygen supply to the central basin hypolimnion.

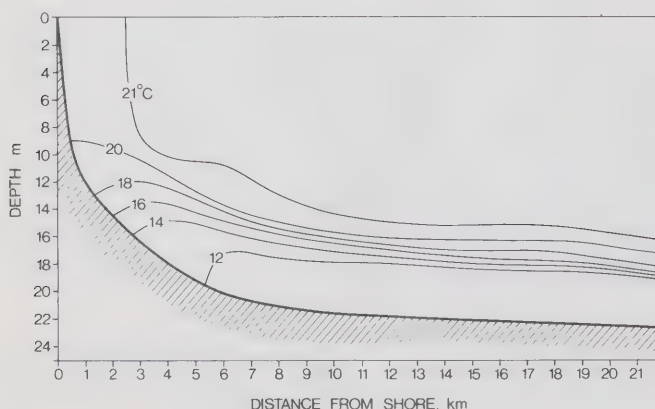


Figure 3 Temperature cross section taken perpendicular to the north shore of the central basin midway between Pointe aux Pins and Point Pelee.

## Special Lake Studies

The goal of this study is to measure and to model vertical circulation and thermal structure in a large fjord lake (Kootenay Lake, British Columbia). It is hoped to be able to predict the effects of an alteration of the hydrologic regime on the thermal structure. This study impinges on the reevaluation of the Columbia River Treaty.

The work included the collection of six weeks of continuous data from a moored velocity and temperature profile during the period of strong autumnal storms, and a supporting data set which included wind speed and direction over the lake surface, radiation measurements, current measurements, and temperature profiles at a number of locations in the lake.

Development of two-dimensional models of the circulation and thermal structure continues. These models incorporate recent progress on the modelling of turbulent transfers in stratified flows in order to account for the dynamics of both surface mixing and subsurface river-induced mixing.

A typical result of the fall measurement program is presented in Figure 4. Daily average profiles of temperature, current speed and direction illustrate the intense zone of current shear associated with the thermocline region. These measurements will be compared to the model predictions in order to evaluate the capability of modelling systems of the thermal structure of lakes.

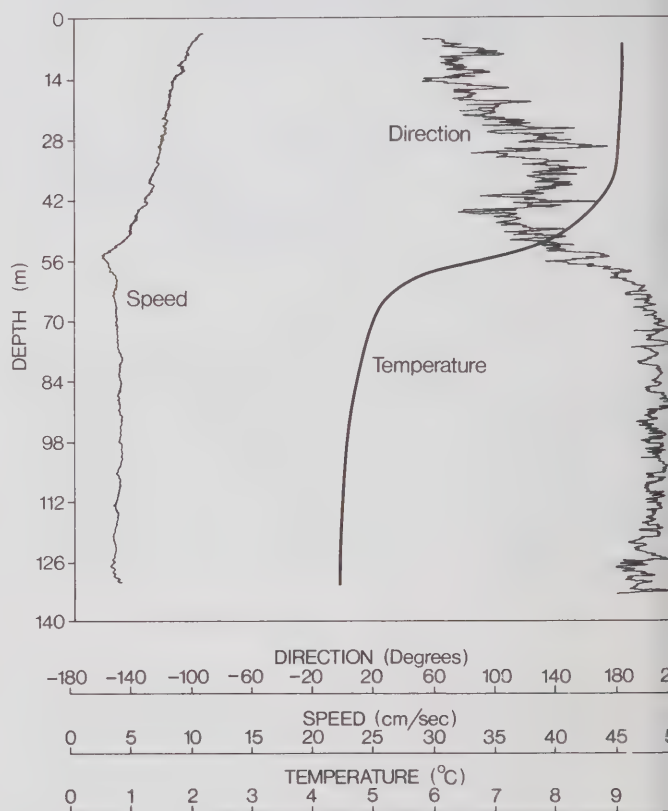


Figure 4 Mean temperature and current profiles, November 13, 1977, Kootenay Lake, B. C.

## Coastal Zone Studies

Coastal waters are increasingly the recipient of the waste products of industrialization and urban growth. Relative ecological pressures in the form of sewage outfalls, chemical dumping, landfill, road salts, heat from electrical power developments and numerous additional loadings conflict with the use of the area for recreational purposes and other activities requiring high standards of water quality. The assessment of this human impact in terms of the resultant effect on biological, chemical and geologic processes in the coastal zone requires an understanding of the complex driving mechanisms for dispersion and transport of effluent constituents. In this context, the Basin Investigation and Modelling Section has conducted a series of field measurement programs at several coastal sites in the Great Lakes to characterize, in a climatological sense, coastal zone water movements.



The specific sites are chosen to be representative of a road band of Great Lakes shoreline over which dispersal conditions appear to be similar and which are areas of intense, or potentially intense, utilization. It is thought that the measurements of average flows can reasonably be extrapolated to areas of similar bottom topography and similar shoreline orientation to the prevailing wind; at least within the confines of the Laurentian Great Lakes. Classification of flow regimes, their frequency of occurrence and average duration are properties that are important indications of the potential for dispersion at a given site.

The current and thermal structure in the coastal zone is extremely complex, with long time-series records showing large variations from place to place and season to season. From the measurements made to date, the most prominent features of coastal flow regimes are the periods of shore-parallel currents persisting in one direction for days at a time, interspersed with periods of variability, weakening and often reversal of the currents.

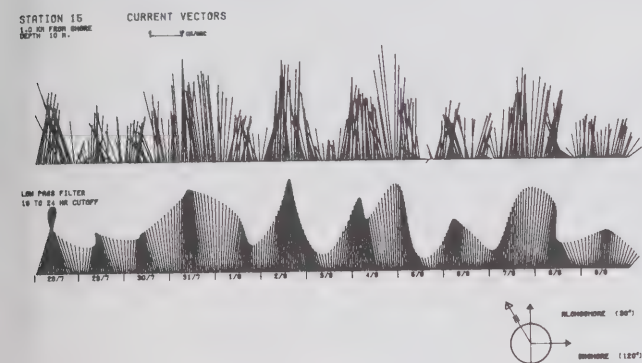


Figure 5 Time series vector plot of currents in the coastal zone at Douglas Point, Lake Huron.

Figure 5 shows a typical current record from a mooring located in the nearshore zone, approximately 1 km from shore, off Douglas Point, Lake Huron. The record is continuous and illustrates the strongly shore-parallel currents which persisted for a period of 13 days. The smoothed trace below shows the result of applying a low-pass digital filter to the data; used here to eliminate events occurring with a period less than 24 hours. Since significant changes in coastal flow are linked with major wind events and these are associated with time intervals on the order of several days, mass transport information is lost by the use of the less complicated filtered data set. This can be seen qualitatively by comparing the vector and its smooth counterpart as displayed.

The instantaneous variations of the currents about the mean values may be considered as a random turbulent component of the vector. The higher frequency information can then be used to estimate effective turbulent diffusivities from the data, and hence the dispersal or mixing properties of the flow. Using statistical means detailed calculations of mean flow properties, horizontal turbulence and dispersive characteristics are prepared for a descriptive analysis of the coastal zone flow characteristics. Persistent shore-parallel flow is of particular interest because it is during such episodes that coastal flows assume their boundary layer character.

Alongshore ( $\bar{u}$ ) and onshore/offshore ( $\bar{v}$ ) variation of mean velocities for a period of persistent northeast flow near Douglas Point, Lake Huron, shows the flow structure within the coastal boundary layer (Figure 6). The alongshore component of flow attains a maximum (20 cm/s) about 2.5 km from the shore. The maximum divides the boundary flow into two regions, an inner boundary layer in the traditional sense where shore and bottom friction brings the flow to a halt at the shoreline, and an outer boundary layer extending from 2.5 km to about 10 km offshore in which the open lake circulation interacts with the shoreline.

#### Water Quality and Aquatic Ecosystems Modelling

The main objective of the water quality and aquatic ecosystems modelling is to develop a general modelling framework which simulates the temporal and spatial distributions of dissolved and suspended materials in the nearshore and offshore zones in

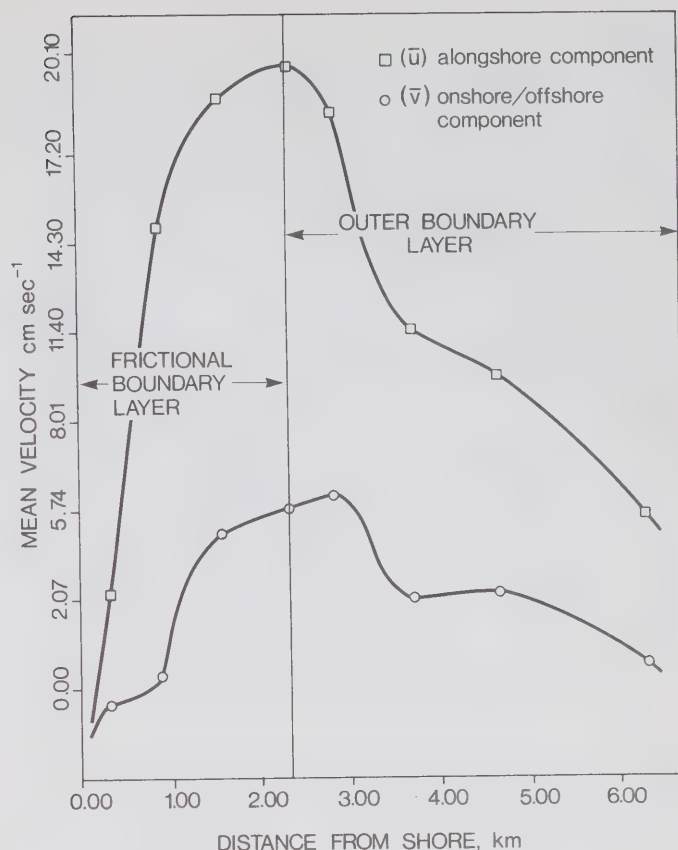


Figure 6 Coastal boundary layer at Douglas Point, Lake Huron.

lakes. Based on the general framework, basic limnological research results in the physical, chemical and biological sciences can be combined into an overall simulation model which is capable of simulating the effects of contaminants in the aquatic ecosystem. Over the past two years, much of the modelling effort has been concentrated on the lower Great Lakes.

#### Lake Ontario Models

A review and evaluation of presently available modelling capability has been completed for Lake Ontario. The study considered three aspects of water quality, (i) seasonal variations, (ii) long-term variations, and (iii) spatial variations. In the seasonal simulation, a diagnostic study showed that net sedimentation is a complicated function of settling and resuspension and that uptake of inorganic phosphorus below the thermocline may often be of the same magnitude as the uptake in the photosynthetic layer. Presently available plankton models do not properly address any of these questions.

The long-term analysis indicated that the available estimates of nutrient loadings to Lake Ontario during the last decade are surrounded with uncertainties. However, a trend analysis of nutrient and plankton concentrations in the lake during the same period suggested some improvements during recent years (see Figure 7). The spatial analysis included three-dimensional data interpolation, hydrodynamic simulations, transports of heat and nutrients, and three-dimensional plankton models of Lake Ontario. It was found that hydrodynamic simulations need improvement in nearshore areas, in particular during the stratification season. It was shown that by a judicious combination of three-dimensional model results and nutrient-plankton observations, one can arrive at interesting conclusions regarding nutrient exchanges across the thermocline and between inshore and offshore waters. One conclusion is that the resulting internal loading to nearshore zones exceeds the direct effect of external loading and, consequently, the response of the nearshore zone is intimately linked to the whole lake response. Some of the review results have been presented to the IJC Phosphorus Management Strategies Task Force.

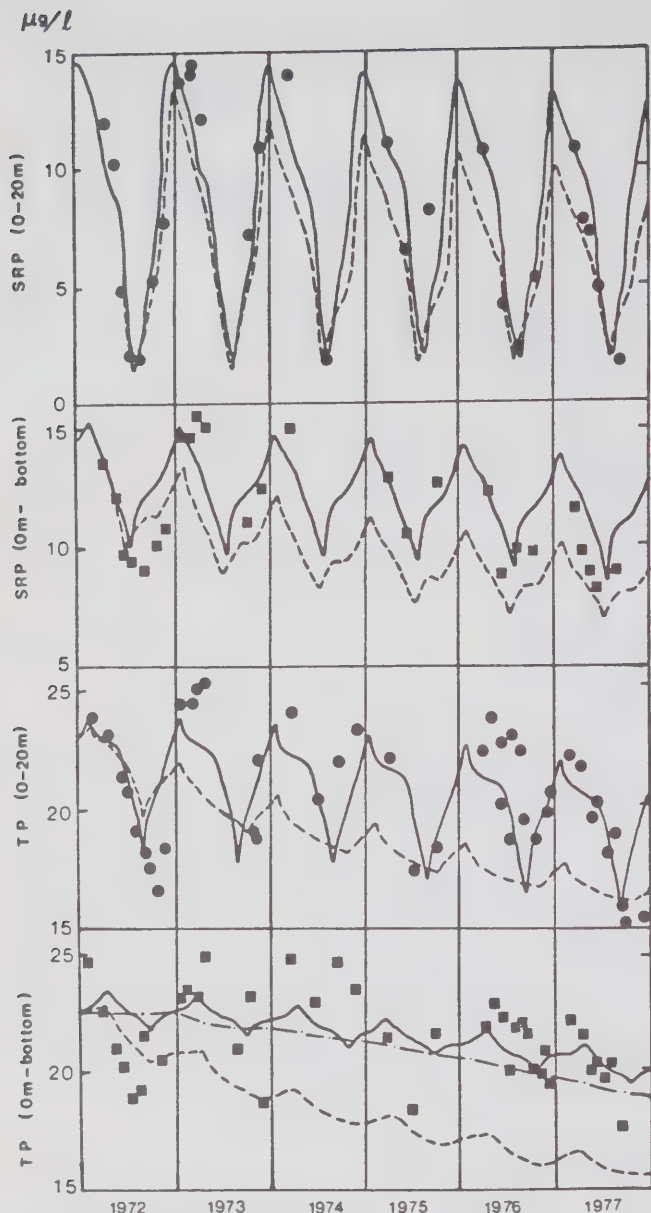


Figure 7 Long-term simulations for environmental conditions observed during 1972-1977 and for a linear approximation to observed decrease in phosphorus loading. Circles denote observations in epilimnion, squares represent whole lake, solid lines apply to periodic model for 1972, dashed lines represent model with best fit to 1972 seasonal variations, dash-dot line is solution from total phosphorus model.

#### Lake Erie Model

In parallel with the Lake Erie observational programs, a water quality model has been developed with particular emphasis on the thermocline submodel. The precise prediction of the stratification cycle undoubtedly holds the key to the understanding of the water circulation, biological productivity, toxicant transports, nutrient cycling, and oxygen depletion in Lake Erie. By comparing model results to the 1967-1978 lake temperature data, it was shown that the one-dimensional thermocline submodel is rather promising in terms of both accuracy and efficiency. This leads to the construction of the framework for simulating the nutrient-plankton relationships and the dissolved oxygen conditions. Preliminary results indicate that the oxygen depletion is sensitive to both climatic variations and man-made loadings. The exact proportions of influence of these factors will be determined by the model. The modelling framework has also been applied to the dynamic balance

of the heat content as well as the chloride concentration in the lake. In these applications, the meteorological data and the chemical loadings for 1967-1976 have been analyzed and made available for modelling and research purposes. A new three-dimensional interpolation program capable of fitting lake data to follow consistently with thermal structures has also been developed.

#### Coastal Zone Simulation Models

A package of coastal zone simulation models has also been developed by the Basin Investigation and Modelling Section. Central to this modelling package is the ability to simulate the behaviour of effluent plumes in the far-field range (0.5-2 km) through which materials are transmitted from outfalls to offshore regions. These materials may include radionuclides, sewage waste bacteria, heat, organics, heavy metals, and toxicants. The mechanisms of the coastal currents and turbulent mixing are more complex in this region than in the open waters. Thus, it is necessary to rely heavily on the experimental results in the model formulations. An example is the use of a semi-empirical, length-scale-dependent diffusivity to simulate the turbulent mixing.

The concept of limited-use zones in the coastal area allows effluent concentrations within these regions to exceed the acceptable criteria. This concept is central to the administration of water resources. While specific studies must be undertaken for each new and major installation, there remains a need for generalized and simple methods of estimating the size, and configuration of effluent plumes under realistic environmental conditions. An example of the products of the model package is a plot of horizontal contours of probability that the dilution of a hypothetical tracer effluent of given source strength and location will not exceed a certain value on an annual basis. In this regard, a marriage of coastal climatology with simple, steady-state plume models is proposed as the best way of producing dilution diagrams around effluent sources. The coastal flow data can be classified into a manageable number of distinct regimes according to strength and direction of alongshore currents. The probability of occurrence of each classification can be estimated as the fractions of total record length during which the flow regime falls within the classification limits. Using the appropriate steady-state plume model, the configuration of the plume is calculated for median environmental conditions of each classification. This, together with some estimates of worst case plume configuration with maximum concentrations, would summarize the mixing capacity of the locations. Preliminary results have been coordinated with other agencies for submission to the IJC.

#### SPECTRO-OPTICS AND REMOTE SENSING

The Environmental Spectro-Optics Section at NWRI is concerned with the scientific evaluation of the aquatic environment (inland lake systems including rivers and basins) utilizing the optical properties of water and the principles of spectro-optical physics and radiative transfer theory. Multispectral data acquired from *in situ* airborne and satellite optical sensors are integrated (through optical modelling, methodology, sensor development, and data collection and analyses) on the basis of the interaction of both natural and artificial radiation with inland water masses. During the past several years, most of the Section's effort was concentrated on the Great Lakes. Some of the pertinent studies included:

- (i) The design and fabrication of a spectrally-selective dual optical chamber (BACH) which allows for the simultaneous determination of the backscattering and absorbing properties of natural waters in a single instrument, one-measurement technique.
- (ii) The establishment of both a digital analysis and display system and software methodology to evaluate digitally acquired data from the NIMBUS and LANDSAT satellites.
- (iii) The development of *in situ* optical models which may be directly applied to water quality determination from sensors mounted below or above the water/air interface.
- (iv) The delineation of groundwater flow pathways within a freshwater basin utilizing the four radiance bands of the LANDSAT series of environmental space vehicles.
- (v) The delineation from space of vegetative crop cover based upon the ability of the groundwater to sustain such vegetation in southern Ontario.
- (vi) The initiation and execution of an extensive coordinated satellite/*in situ*/airborne project with the Canada Centre for Remote Sensing and MONITEQ Ltd. to develop predictive *in situ* water quality methodologies and atmospheric algorithms for use with the NIMBUS-7 satellite.



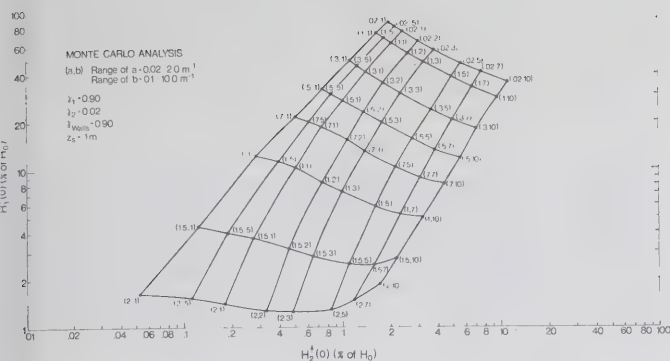


Figure 1 Predictive methodology developed for use with the BACH underwater device

Figure 1 illustrates the predictive methodology (based on a Monte Carlo simulation of photons interacting with natural waters) developed for use with the BACH underwater device. The irradiance recorded in one of the BACH chambers (with a predominantly "white" reflecting bottom) is  $H_1(O)$ . The irradiance recorded in the other BACH chamber (with a predominantly "black" reflecting bottom) is  $H_2(O)$ . Figure 1 enables the  $H_1(O)$  and  $H_2(O)$  measurements to be utilized in a direct determination of the absorption coefficient,  $a$ , and the scattering coefficient,  $b$ , of the water sample.

Figure 2 shows the spectral dependence of inherent optical properties determined for nearshore waters of Lake Ontario. The inherent optical properties displayed include the total attenuation coefficient  $c$ , the scattering coefficient  $b$ , the absorption coefficient  $a$ , the forward scattering probability  $F$ , the scattering albedo  $\omega_0$ , and the backscattering probability  $B$ . Figure 2 suggests that the absorption and scattering occurring within a water column are not necessarily mutually independent processes.



Figure 3 Inferred directions of groundwater movements

Figure 3 delineates a schematic computerized illustration of the inferred directions of groundwater movements within a portion of the Big Creek watershed in southern Lake Ontario utilizing digital LANDSAT data. The crosses indicate discharge areas, the dots indicate recharge areas, and the blank spaces indicate transition regions.

Figure 4 denotes the clustering which results from correlating the Bands 5 (visible red) and 7 (near-infrared) responses of the LANDSAT vehicle during a summer overpass of a heavily-vegetated freshwater basin. The absorptive and reflective properties of phreatophytic vegetation enable a classification of the basin in terms of its principal groundwater regimes defined by the proximity to the surface of the water table.

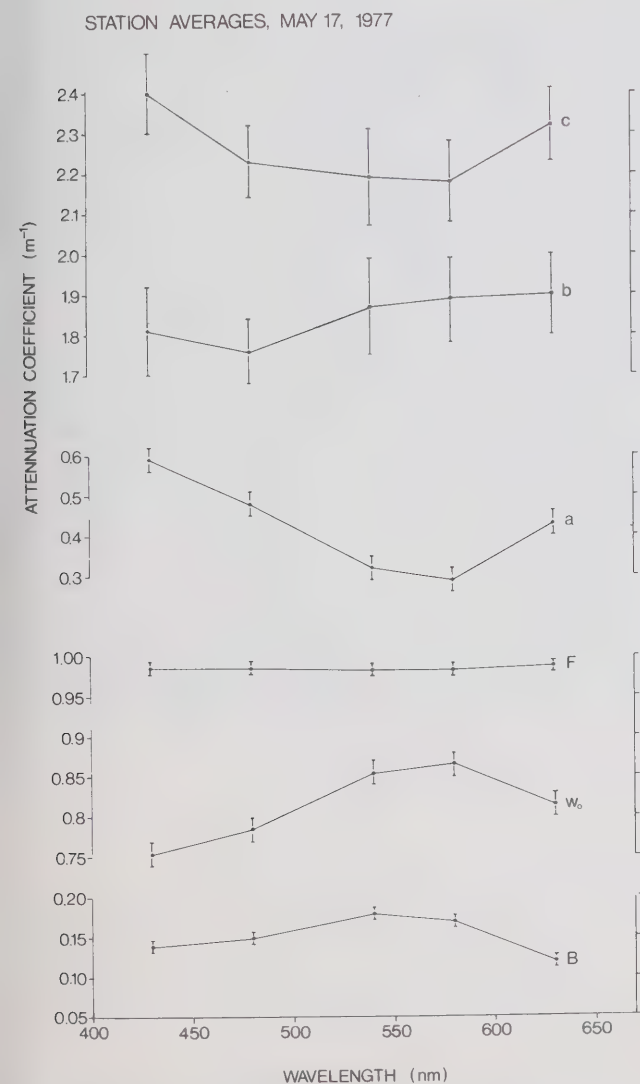


Figure 2 Optical properties of nearshore waters (Lake Ontario)

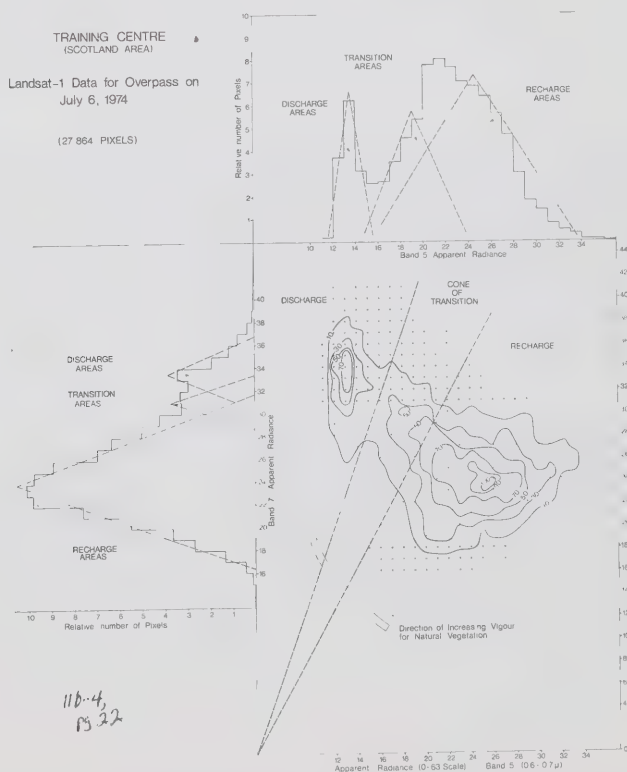


Figure 4 Correlation of bands 5 and 7 responses of LANDSAT vehicle during a summer overpass of a heavily vegetated freshwater basin



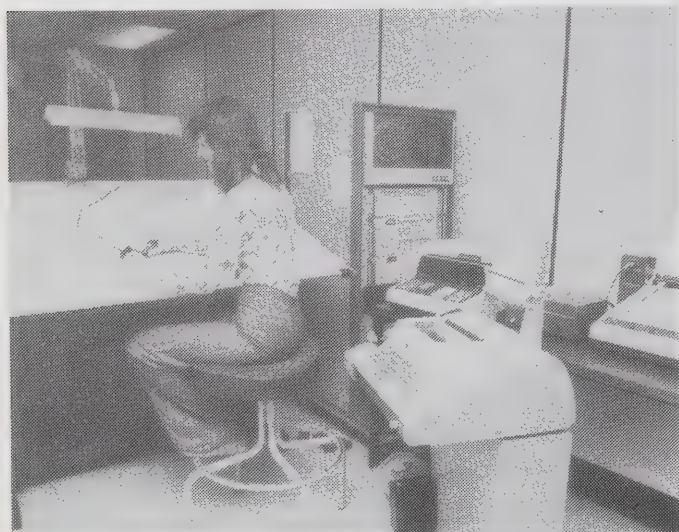
## DATA MANAGEMENT SECTION

Operational data management including reduction, conversion, analysis, dissemination and archiving for major surveillance and scientific research data acquisition programs at NWRI is provided by the Data Management Section. EDP systems development services are also provided to all departmental components at the CCIW in accordance with approved allocations by program. Some of the general service functions performed within the Data Management Section are depicted in the captioned photographs in this report.



1. Editing time-series data sets, using a light pen to correct or delete anomalous values stored on magnetic tape files.

Fundamental reviews of historical current, and projected computing requirements at CCIW resulted in approval to upgrade the computer facility, thus requiring a comprehensive benchmarking, evaluation, and selection process for current generation computing facilities. The Data Management Section was a major participant in all of these computer acquisition processes. The new computing facilities, installed during June 1979, include the support of interactive data processing network computer communications, graphical display generation, and also support the Departmentally-accepted data base management system (System 2000) for the virtual integration and research exploitation of various related environmental data bases.



2. Digitizing a map segment onto magnetic tape for use in the production of computer plots of environmental data or derived information.

The subsequent thrust of the year related to a two-generation upgrade of EDP technology at CCIW. This included installing new equipment, learning and adapting to new systems software, converting or rewriting existing applications software in

excess of 300 programs, learning to use new programming languages, compilers, adapting to interactive computing methods and procedures, retraining a large community of users, developing new operational structures and procedures, and using new data base management systems technology for data integration, access, security, and analysis.



3. Retrieving environmental data for research scientists from the American EPA STORET system in Maryland, U.S.A.

In addition to the specific activities identified below, a wide variety of computer based applications were developed during the year under 66 supported studies. These were implemented on behalf of the various user groups and individual research scientists or to service major ongoing programs at the Centre, such as the Great Lakes Surveillance Program.



4. Organizing backup files of environmental data on magnetic tape in a fire proof vault, rated to withstand four hours temperatures up to 2000°F.

A few of the more significant tasks recently undertaken in collaboration with other groups, included:

- (i) The computer-based automation of a large group of chemical laboratory functions with numerous complex analytical procedures including the lab management functions, process control functions, data reduction and conversion functions as well as data base management, quality control, reporting, data-file update functions.
- (ii) Development and operational implementation of international data handling, processing, publication, report dissemination and archiving facilities for a Global Water Quality Monitoring Program for the World Health Organization.



- i) Complete redesign and redevelopment of data acquisition, reduction, and processing facilities for a selective national network of solar radiation stations.
- ii) Standardization, documentation, and integration of major current and historical scientific data files into specially designed data base structures and into the NWRI archives.
- iii) Preparation and submission of major historical and current Great Lakes Surveillance data files to the US EPA, for inclusion in the STORET data base system under a formally negotiated exchange program allowing for Canada's reciprocal free access to the STORET data base by NWRI.
- iv) Generalization of interactive computer-based systems to provide for quality control and editing of correlated scientific data sets using the subjective judgement of the technical editor, or by calling upon dynamic routines to automatically interpolate and flag missing or widely divergent values.
- v) Development of colour graphics display, manipulation and enhancement facilities for satellite imagery data files in support of Spectro-Optics research activities.
- vi) The operational implementation of a subset of the National Water Quality Data System (NAQUADAT) at NWRI.
- vii) Development of data management, storage, and analysis facilities for acid rain and related data bases in support of a high priority national program.

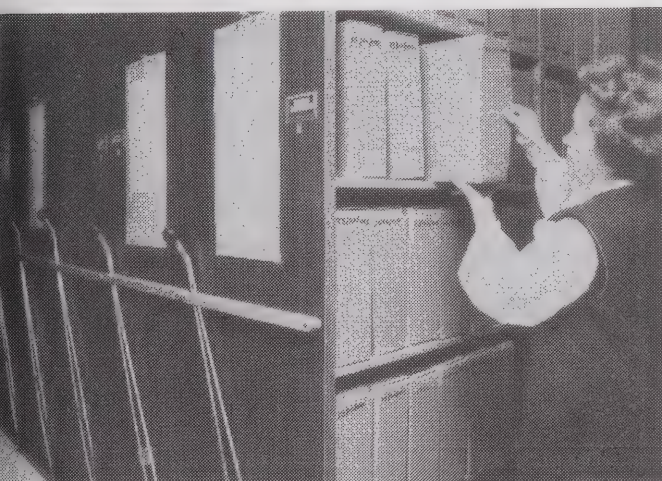


Figure 1 Retrieving environmental source data documents from consolidated archival storage facilities at CCIW.

The Data Management Section also supplied various raw data sets, and a variety of computer-produced statistical or graphic data summaries in response to requests from within the Department, other governmental agencies and the private sector.

A final substantial contribution to the Centre is made through the provision of continuing professional EDP consultation services to computer users and to management on demand.

## LONG-RANGE TRANSPORT OF AIR POLLUTANTS

The Long-Range Transport of Air Pollutants (LRTAP) Program is a multidepartmental effort to assess the extent and degree to which air-transported materials are causing damage and deterioration of the ecosystem of Canada. The NWRI contribution is primarily devoted to evaluation of the effects on the aquatic regimes and is comprised of research studies in four of the Research Divisions. Present emphasis is on the effect of acidified precipitation, but precipitation deposition measurements conducted cooperatively with other CCIW groups also include the major ions, biological nutrients, trace elements, and synthetic organic contaminants.

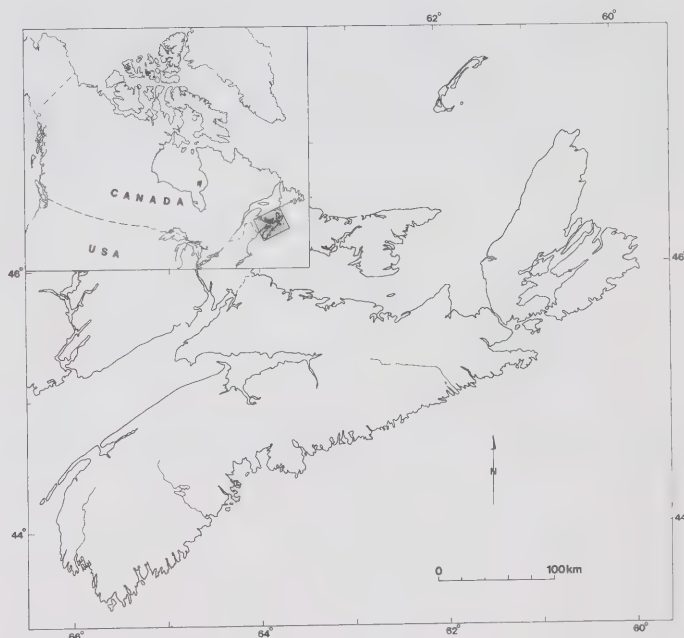


Figure 1 Location of Nova Scotia rivers

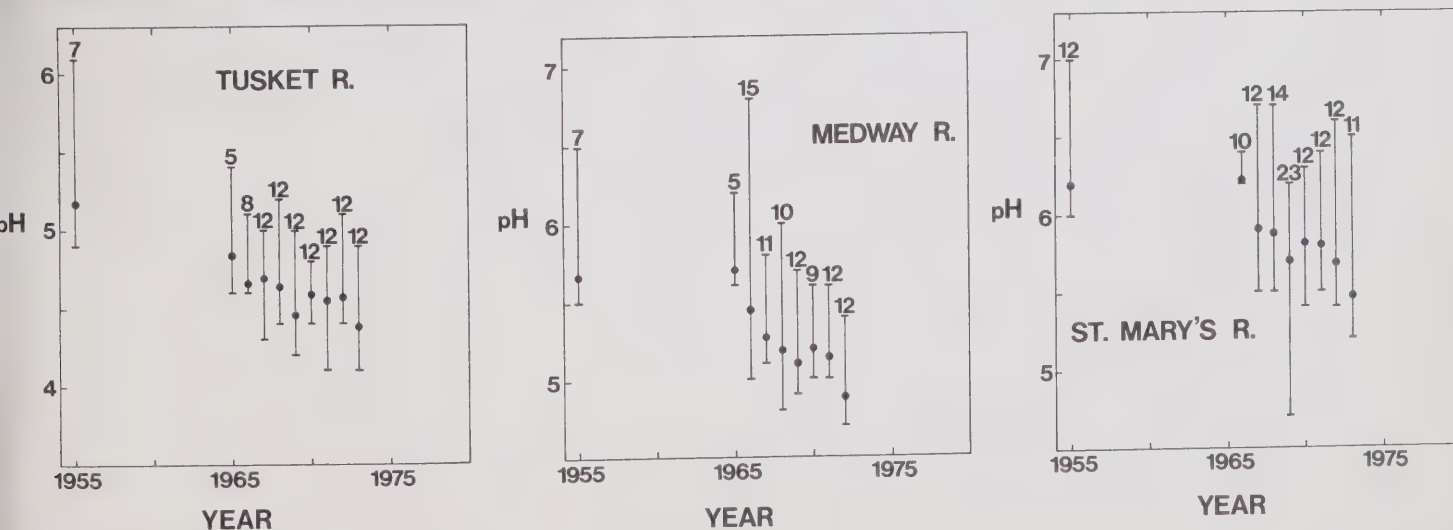


Figure 2 Discharge-weighted mean  $H^+$  as pH, for three Nova Scotia rivers

The Aquatic Physics and Systems Division provides planning and coordination of the Environmental Management Service portion of the LRTAP Aquatic Effects program which is carried out in conjunction with the Department of Fisheries and Oceans. Contemporary surface water chemistry surveys are planned for areas of Canada east of Manitoba and are carried out by components of the Inland Waters Directorate and Canadian Wildlife Service to define the sensitivity of the aquatic regime to acidification and, using historical data where available, to document present status and rates of deterioration. Specific watershed studies are planned in cooperation with Canadian Forestry Service, Department of Fisheries and Oceans and other EMS units wherein detailed measurements of the basin ecosystem interactions and responses to the atmospheric deposition are carried out. NWRI is primarily committed to the extensive studies being carried out cooperatively by Great Lakes Biolimnology Laboratory, Great Lakes Forestry Experiment Centre, and Ontario Ministry of Natural Resources at the Turkey Lakes Experimental Watershed north of Sault Ste. Marie, Ontario.

The evidence of influences of abnormally acidic precipitation on poorly buffered watersheds is shown by studies conducted on the streams which drain southwestern Nova Scotia (Figure 1). Highly reliable measurements of the major ionic content of the waters were made in 1954-55 and then continued on a monthly basis from 1966 to 1973. As shown in Figure 2, the pH of several rivers decreased from near normal values of 5.5 to 6 to less than 5 over this period, with little change in calcium concentration (Figure 3). It has been well documented that fish reproduction and survival become endangered when pH of waters fall below 5 to 5.5. It appears that the rivers for which data are shown in Figure 1 can no longer provide an Atlantic Salmon spawning habitat. Summary of the historical surface water records over the sensitive areas of Canada will provide an objective measure of the regime alteration by LRTAP.

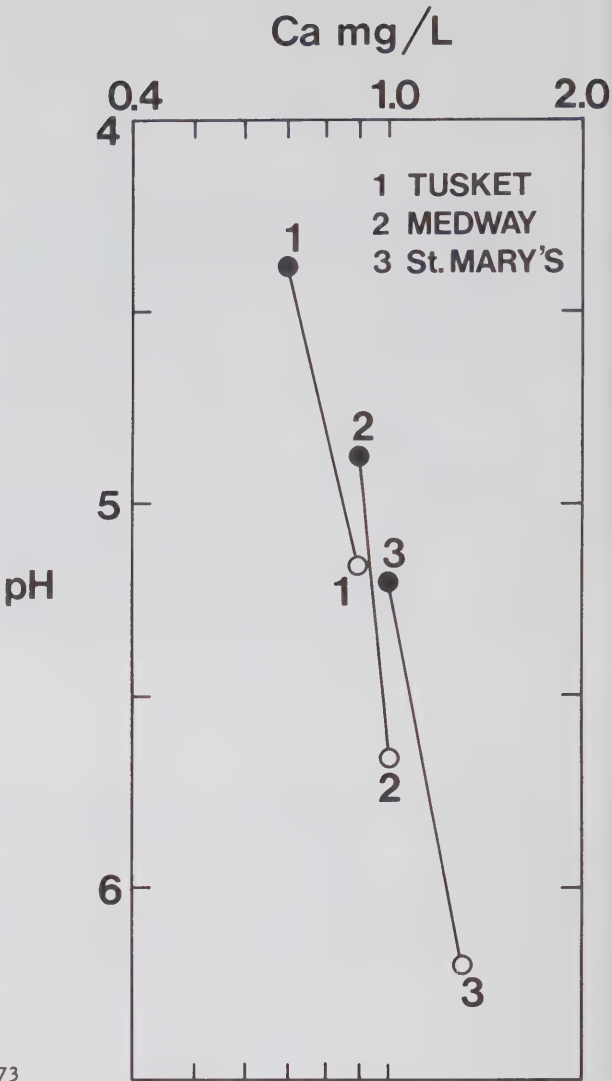


Figure 3 Log Ca<sup>++</sup> versus pH for the three Nova Scotia rivers, 1954-55 and 1973



## **ANALYTICAL METHODS DIVISION**



The Analytical Methods Division is responsible for research and development of methodologies for chemical and microbiological pollutants in the aquatic environment and for conducting national and international quality control programs.

In order to fulfill this responsibility the Division undertakes national and regional programs in analytical chemistry (including electrochemistry), electron microscopy and microbiology. The objectives of these activities are:

To develop new and improved analytical methods which are accurate, cost effective, sensitive and unambiguous for the identification and quantification of contaminants in the aquatic ecosystem.

To play the lead role in documentation, validation and standardization of analytical methodologies and institute quality assurance and control programs for ensuring accuracy and reliability of analytical data.

To provide a service utilizing sophisticated instrumentation and facilities such as electron microscopy, gas chromatography - mass spectrometry, and Clean and High Hazard Laboratory.

To develop, assess and field evaluate more sensitive and reliable sampling and analysis techniques for bacterial, fungal, viral and biochemical indicators in natural waters, wastewaters and sediments.

To develop realistic microbiological water quality criteria for the protection of public safety.

To evaluate microbiological techniques for the assessment of mutagenic/carcinogenic and toxic properties of waters and effluents.

The staff of the Division maintains close contact with scientists in other Canadian federal departments, provincial governments, U.S. federal and state agencies and universities. In some cases collaborative studies are undertaken. The Division strongly supports the work of the International Joint Commission, the International Standards Organization, American Society for Testing and Materials, Federal Interdepartmental Committee on Pesticides, and Association of Official Analytical Chemists, by membership on committees and task groups.

The Analytical Chemistry Research Section concentrates on the development of new techniques and the improvement of existing techniques for the identification and quantification of chemical constituents of water, sediment and biological material. Techniques frequently used include high pressure liquid chromatography, gas-chromatography, gas chromatography-mass spectrometry, electrochemical techniques and spectroscopy.

The Microbiology Laboratories Section has two main program areas. One is to develop and evaluate microbiological and mycological methodology and criteria for monitoring, assessing and maintaining water quality from the viewpoint of health hazards and eutrophication. The other is environmental research on the effects of effluents on water bodies, the determination of the distribution of specific microorganisms in polluted water and their roles in the aquatic ecosystem.

The Quality Assurance and Methods Section is responsible for establishing quality assurance control programs to monitor laboratory performance to ensure that data generated are valid and compatible on a regional, interagency, interdepartmental, national and international basis. In addition, other important activities include the development of standard reference materials (water, sediment, and biota samples) for chemical, and biochemical parameters, and the generation of interlaboratory specifications for precision, accuracy and detection limits. The Section is also responsible for adapting, evaluating, and developing suitable chemical methodologies, and for advice on solving analytical problems encountered in the regional laboratories.

The Clean and High Hazard Laboratory, scheduled for completion in August 1980, will be used primarily for methods development research involving trace contaminants requiring a special ultra-clean working environment and highly sensitive instrumentation. In addition, the laboratory will prepare standards of hazardous compounds and other ultra-pure standards for government service laboratories and participate in quality control programs.

In the Electron Microscope Laboratory, electron microscopy is used as a research aid in water quality studies. Full use is made of the analytical capability of energy dispersion spectroscopy interfaced to the scanning electron microscope. Electron microscopy is an integral part of the research activities into methodology development as well as in the application of these methodologies to the characterization of sediments, the establishment of morphological changes in the presence/absence of toxic elements, and in the determination of bioaccumulation and toxicity.

## ANALYTICAL CHEMISTRY RESEARCH SECTION

An improved methodology for the determination of polynuclear aromatic hydrocarbons (PNA's) in environmental samples has been developed using a high pressure liquid chromatography-multidetector system. This system allows selective and quantitative analysis of various PNA's. The method was evaluated using 22 PNA's including those recommended for monitoring by WHO. The method is able to detect individual PNA's at low parts per trillion level and when compared to existing techniques it is found to be superior in terms of cost, reliability and sensitivity (Figures 1 and 2).

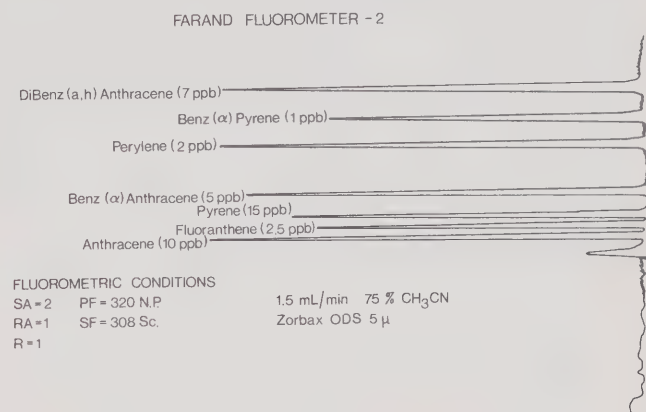


Figure 1 Analytical response of PNA's, using conventional fluorimeter

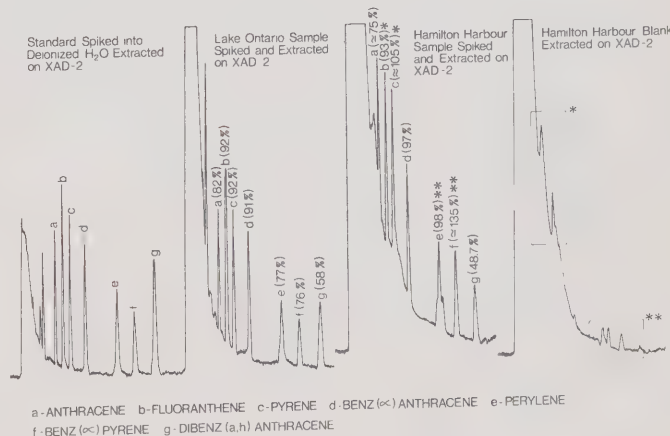


Figure 2 Analyses of PNA's in Hamilton Harbour.

A multidetector - HPLC System is presently under development at NWRI. This system will allow quantitative analysis as well as positive identification of trace organics in environmental samples. To date various detectors have been interfaced in series to obtain qualitative and quantitative data using HPLC as separation technique. These include absorptiometry, fluorescence, polarography, and electron capture detection. Further work will continue to interface other detection systems such as coulometry, ion-selective electrodes and atomic spectroscopy. Existing methods used for positive identification and confirmation of trace organics are based on multi-column GC techniques or GC/MS. It is anticipated that the new system will be far superior to the multi-column approach for confirmation and will prove to be cost-effective when compared to GC/MS.



An improved method for the analysis of carbamates in natural water has been completed. The method has been tested using natural waters from various locations across Canada. The method involves extraction with methylene chloride followed by a suitable cleanup step prior to analytical determination by HPLC - multidetector system. The detection system utilizes the absorption at 205 and 254 nm and molecular fluorescence. Detection limits at low parts per billion have been achieved to date. Work is continuing to extend the scope of the method to cover soil and sediment samples (Figure 3).

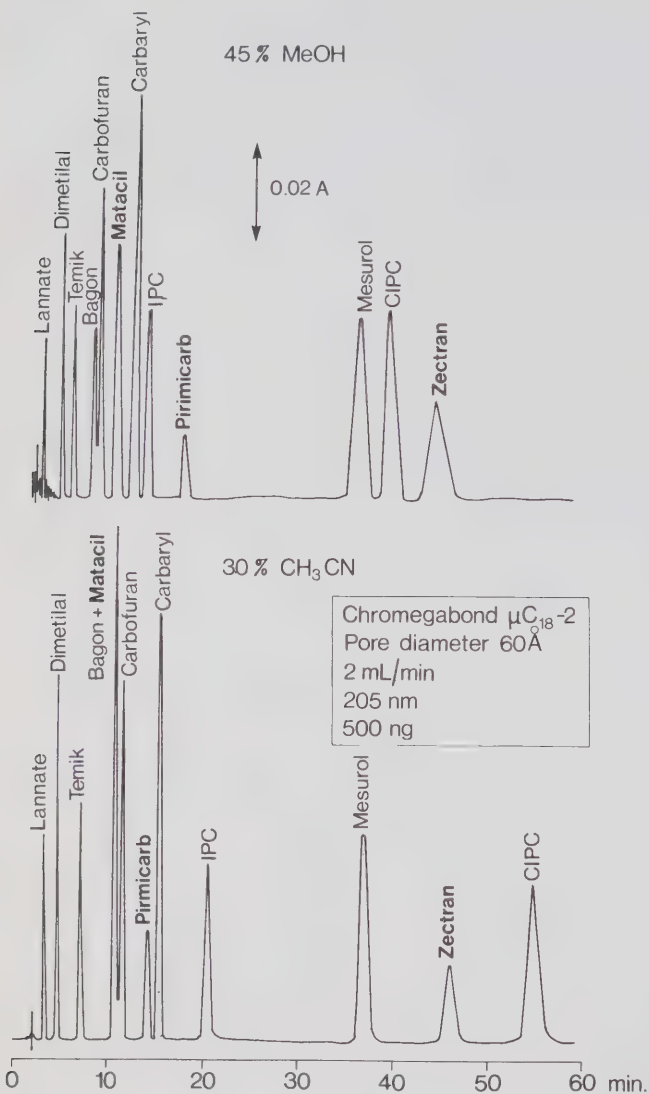


Figure 3 Separation of carbamates using different solvents

Work has continued to improve glass capillary WCOT (wall coated open tubular) columns for GC. A superior procedure was developed for the deactivation of Pyrex borosilicate glass capillary GC-columns. The process involves our basic technique of whiskering the glass surface, followed by leaching with concentrated nitric acid to remove aluminum and boron oxides. These oxides have been shown to exhibit substantial Lewis acid-base activity resulting in broadening of peaks which limit ultimate resolution of the columns. An improved, static coating procedure was also developed which resulted in better coverage of the internal surface. Apart from the superior inertness of these columns, much greater thermal stability was also attained for non-polar and polar liquid phases such as OV-101, OV-1, SE-30, SE-52, SE-54 and OV-17, and Carbowax 20 M. Picogram quantities of "active" compounds may be quantitated without impairment by the tailing of the chromatographic peak (Figure 4). A detailed report is in preparation.

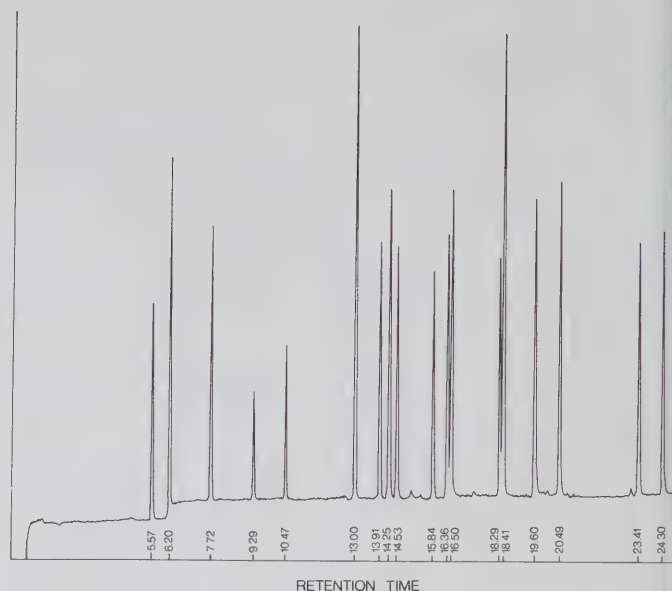


Figure 4 GL chromatogram of various pesticides

An evaluation was carried out of the methods for the quantitative analysis and confirmation of 1,2,3,4 - tetrachlorodibenzo-p-dioxin (TCDD). The method proposed by Dow Chemical Company for 2,3,7,8-TCDD was found to give low recoveries for 1,2,3,4-TCDD. An alternate clean-up procedure was developed utilizing florisil, alumina, and HPLC which resulted in improved recoveries (90 % for 1,2,3,4-TCDD). The extracts were finally analyzed using capillary column - GC and GC/MS. This method was used to obtain baseline data for 1,2,3,4-TCDD in fish and sediment samples from the Great Lakes. It was established that concentrations reported by other agencies for tetrachlorodibenzo-p-dioxins in fish were unrealistically high. Our preliminary data indicate that the sediment sample extracts contain a maximum concentration of total tetrachlorodibenzo-p-dioxin to be 15 ppt, with the mean isomer concentration being around 3 ppt.

Work on the evaluation and verification of analytical methodology for chlorobenzenes in sediment and fish samples was initiated. WCOT capillary columns were employed for the separation using electron capture detection.

A comprehensive study covering the analysis of toxaphene was initiated using capillary column (WCOT) GC and mass spectrometry. Work has been carried out to increase sensitivity of detection of ECD - WCOT glass capillary GC and to simplify the chromatogram by means of alkaline hydrolysis of the toxaphene mixture.

In cooperation with the Canadian Wildlife Service herring gull colonies at Double Is., Scotch Bonnet Is., Mugs Is., Snake Is., Fighting Is., Middle Is., Niagara River, Agawa Rocks, Granite Is., Chaunty Is., L. Ontario, L. Erie and the Detroit River area were screened for persistent contaminants. More than 500 spectra were scanned and various classes of contaminants were identified such as: chlorobenzenes, PCB's, mirex and its metabolites, chlorinated terphenyls, chlorostyrenes and phthalates. Detailed results will be reported separately by the CWS group in an International Joint Commission report.

A study of the parameters affecting the sensitivity of the cold-vapour method for mercury determination using atomic spectroscopy has been carried out. By considering the particular parameters affecting the partitioning of elemental mercury between the liquid and vapour phase, a technique has been developed whereby mercury from a large sample is transferred to a small volume of air. This results in an analytical method for water with a detection limit of  $0.001 \mu\text{g l}^{-1}$  Hg. Changing the conditions under which the elemental mercury is produced enables the different chemical forms of mercury in the sample to be determined. The technique has been evaluated on natural water and precipitation samples.

An analytical scheme has been developed by which the trace metals Cu, Cd, Pb, Ni, Fe, Zn, Mo, V, Cr, Co, Mn, and Al, are

etermined in natural waters at the sub- $\mu\text{g l}^{-1}$  level using atomic emission spectroscopy with argon plasma excitation. The technique has great promise for the routine multi-element analysis of water samples.

The practical application of ion-selective electrodes has been limited by the necessity of using the currently available reference electrodes. In many cases the flow of the internal reference solution into the sample introduces interference either by contributing to the formation of the ion-selective electrode potential or by the reaction with the ion of interest in the sample. A new type of reference electrode has been developed to eliminate contamination of sample from the internal electrolyte. The new electrode is constructed from low impedance ion-selective, solid state electrodes developed previously in NWRI (Cu, Cd, Pd, Ag, Hg, Br, Cl) in equilibrium with a solution of the corresponding ion. These electrodes have good reproducibility and stable intercomparability potentials. They allow for simple preparation of the reference electrodes according to the needs of a particular measurement.

The concept of an automated version of zero-current potentiometry has been developed. The automated system consists of individual instruments previously developed for the manual version of the technique interfaced to a control module. The analytical potential of the technique has been demonstrated for the determination of sulfide, sulfite and cyanide ions.

## MICROBIOLOGY LABORATORIES SECTION

Three Microbiology Laboratories' studies were directly oriented towards the assessment, modification or development of screening procedures employing bacteria and fungi to indicate quickly and economically whether or not a water or effluent contains mutagenic/carcinogenic or toxic chemicals.

These studies are very important and relevant, in the context that over 1000 new organic chemicals are being introduced to the market each year, and at best only about 150 of these can be adequately tested for their hazard potential. With this type of potentially dangerous unknowns being added to water in addition to the many chemicals known to be used and discharged in waste streams, and the possible symbiotic effects among the compounds, the obvious first step must be the screening of effluents and receiving waters for the presence of mutagenic or toxic substances. When such effects have been demonstrated the source of the offending material must be identified and efforts made to curtail the release. Then, the identity of the specific substances must be sought.

One of these studies involves the use of a yeast, *Saccharomyces cerevisiae*, as an indicator of mutagenicity. One advantage the yeast test may have over the bacterial (Ames) test for mutagens is that yeasts are eukaryotes and therefore similar to mammals in that the genetic information contained within the cell is arranged on well-defined chromosomes. During 1979, a variety of *Saccharomyces cerevisiae* strains were evaluated before selecting the D7 strain for further evaluation and field testing. Growth data for this strain were obtained under mutagen testing conditions, and procedures for determining standard mutagen rates were established. By the end of the year, a mutagen assessment test utilizing strain D7 of *Saccharomyces cerevisiae* was standardized with pure chemicals with results similar to those reported in the literature.

Another study involving mutagen/carcinogen assay was related to the standardization of many of the variables which have been encountered in applying the Ames test (using *Salmonella typhimurium*) to water samples. Studies were centred on the sterilization of samples, number of tester strains to be used and the requirements for enzyme activation. A working procedure has been developed and distributed to many laboratories (Canadian and foreign). In time, through the input of these studies to the ISO Working Group on Mutagens, a shorter, less complicated procedure will be developed.

Very promising studies have been carried out on the assessment and development of fast bacterial screening tests for toxicants in water and effluents. The procedures being evaluated were the *Spirillum volutans* test (reaction time 1-120 minutes; cost, \$2 - \$3 per test) and the microtox system (10-15 minutes; cost, \$7 - \$8 per test). These procedures have tremendous potential and are also being thoroughly evaluated by EPA. The NWRI microbiology

laboratory was the only Canadian laboratory with a prototype instrument, loaned by the Beckman Corporation. As a result of demonstrations put on in this laboratory provincial and federal requests for training, data and loan of the prototype instrument have been received. The microbiological short-term tests are aimed at either replacing or supplementing the 96 hour fish-test which costs \$300 - \$600 per test.

In other studies carried out by the Microbiology Laboratories Section an evaluation was carried out of the effect of oil and oil dispersants on the microbiological, and the geoaquatic and phycomycete fungal populations in five artificial ponds containing oligotrophic Lake Huron water. In this study it was observed that the addition of oil or oil plus dispersant to the pond waters stimulated the growth of several microbial species although the total microbial biomass did not increase significantly. Also, a selection of 30 aquatic fungi were isolated into pure culture and were tested for their ability to utilize crude oil, the dispersant (Corexit) and the combination of crude oil plus dispersant.

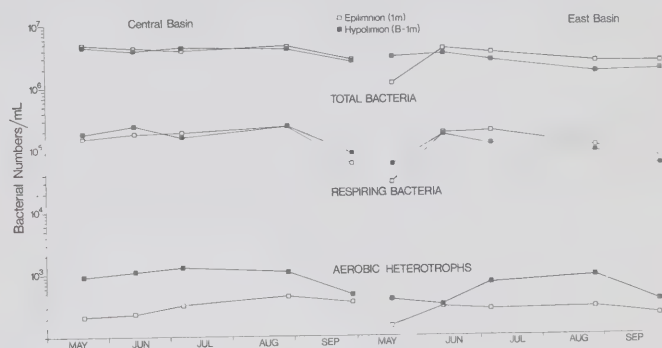


Figure 5 Bacterial distributions in Lake Erie, 1979

During the year, five cruises on Lake Erie were successfully completed to study microbial oxygen depletion (Figure 5). On each cruise, nearly 180 water samples from 15 stations were collected and processed for total, respiring and heterotrophic bacteria (Figure 6). Bacterial populations were related to dissolved oxygen, particulate organic carbon and particulate nitrogen to ascertain the bacterial role in oxygen depletion. The analysis of data indicated:

- Epilimnion bacterial densities were slightly higher in the Central Basin than the East Basin.
- Hypolimnion bacterial densities in the Central Basin were twice that of the East Basin values.
- Bacterial densities reflect the difference in volumetric depletion rate of oxygen in the Central and East Basins.
- Particulate organic carbon in the hypolimnion of the Central Basin was nearly 30% higher than that of the East Basin.

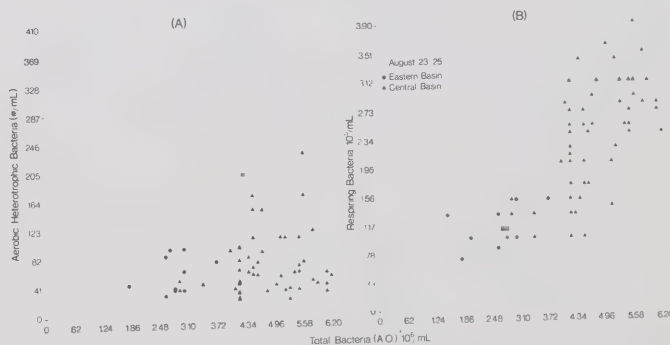


Figure 6 Scatter diagram showing (A) the relationship between aerobic heterotrophs and microscopic counts; and (B) respiring bacteria and microscopic counts, in Lake Erie, 1979



Bacterial water quality studies of the international connecting channel, the Niagara River, were carried out, involving 11 surveys of the Upper Niagara River from May to December. During each survey, water samples were processed for total and fecal coliforms, fecal streptococci, aerobic heterotrophs, *Pseudomonas aeruginosa* and *Spirillum volutans* toxicity. The accumulated data from this study will be used in support of IJC references.

Three studies involving the application of the zonal grid procedure to assess microbiological implications of point source discharges into lakes were carried out in 1979. Each two-week point source study involved the collection of 240 samples and the testing of these samples for health indicator bacteria, heterotrophic bacteria, bacterial biomass and oligotrophic bacteria. The data from this study again confirmed the validity of the zonal grid sampling technique to assess the effects of point source discharges on the Great Lakes.

## QUALITY ASSURANCE AND METHODS SECTION

Analytical methods used in the Water Quality Branch laboratories currently have performance statistics based on data obtained at one concentration by a single operator. For environmental data obtained from several laboratories, it is essential to obtain interlaboratory performance statistics for real test samples at several concentrations in order that the data stored in the National Water Quality Data Repository (NAQUADAT) be more meaningful and useful to present and future users. Therefore, several specially designed interlaboratory quality control studies of natural water were run in 1979 for almost every inorganic parameter determined by the Water Quality Branch laboratories; namely, the major ions, trace metals, nutrients and the physical parameters.

Several National Quality Control Studies were designed and conducted in 1979. They include studies on trace metals and herbicide acids in water; mercury, arsenic and selenium in sediments; and PCB's in wet sediment. As part of the on-going inter-regional quality control program, natural water and some sediment samples were distributed monthly for the analyses of a wide range of parameters routinely determined in Water Quality Branch laboratories. The purpose of this program is to identify quickly any anomalies in data caused by analytical methodologies (including sampling and handling procedures). The need for further methods development can then be assessed and initiated with minimum delay.

A prerequisite of quality control studies is the verification of sample integrity, from the initial sample preparation to the final analysis. Although many parameters have been analyzed routinely for many years, both quality control studies and stability data are lacking. In two stability studies, the medium term stability (up to 1 year) of PCB's in lake sediment and of arsenic and selenium in synthetic and natural waters was investigated under various storage conditions. The results will provide valuable information for the collection, preservation and storage of samples for future surveillance programs. An investigation of sediment sample storage conditions for organochlorine pesticides was also initiated.

Several sediment reference materials were prepared by the Section for use in methodology standardization, calibration, quality control studies and for evaluation of contract laboratories. Such reference materials include mercury, trace metals and the first successfully prepared PCB's in two different dried lake sediments. These materials were divided into several thousand subsamples for long term use, and have been analyzed extensively and the homogeneity well tested. Similarly, several well characterized bulk water samples (200-1200 litres) were used as reference material for multisample, multimethod interlaboratory studies of inorganic parameters. These samples were also used for national and international quality control studies.

The Section has provided a lead role in the quality assurance for the International Joint Commissions' Great Lakes International Surveillance Program. Six international studies for IJC were designed, prepared and distributed. These studies include arsenic and selenium, major ions, trace metals and total phosphorus in water, toxic organics in fish and PCB's in wet sediments.

Under the auspices of the Federal Interdepartmental Committee on Pesticides the Section acts as the coordinator for water and sediment check sample program in Canada. A study of herbicides in water was designed and conducted. Section personnel have also been involved in collaborative studies for standardization of analytical methods through the Association of Official Analytical Chemists and the American Society for Testing and Materials.

As a second major responsibility, the Section has been active in advising, adapting, evaluating and developing analytical methods to be used in the Water Quality Regional Laboratories. Upon request from the Western and Northern Region, an investigation to develop a method for some acid and neutral herbicides in water and sediment was initiated. A method to improve the speed and sensitivity of silver analysis in water was developed in cooperation with Water Quality Branch, Ontario Region. Other methods for such elements as arsenic and selenium in water, fish and sediments have also been developed, and four of these methods have been approved for inclusion in the WQB Methods Manual.

## ELECTRON MICROSCOPE LABORATORY

The Electron Microscopy Laboratory was employed in various activities making full use of the analytical capability of the energy dispersive spectrometry system (EDS) interfaced with scanning electron microscope (SEM). In a systematic study, optimal instrumental conditions were established to provide reproducible and accurate analytical results. This was achieved by quantitative determination of specimen mass losses (Figure 7). The specimen damage and associated loss of mass were reduced to a negligible acceptable level.

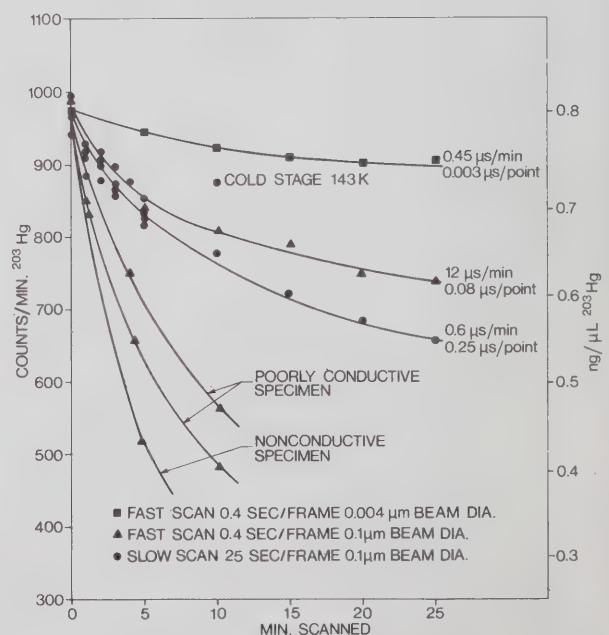


Figure 7 Specimen mass losses during energy dispersive spectrometry

Qualitative and quantitative analyses of inorganic pollutants and some of their organic complexes associated with sediment and suspended particles are now possible with a high degree of accuracy. The results obtained by SEM-EDS system, verified by atomic absorption spectroscopy (AA) and by analysis of certified



standards, are showing consistently close agreement. A simultaneous quantitative analysis of 12 elements can be executed within 20-minutes. Efforts are being made to reduce this time requirement by adoption of a more efficient computation method. This nondestructive analytical method is especially useful in studies involving association of heavy metals with biological and nonbiological components of the aquatic environment.

A method for the presentation of the ultrastructure of zooplankton stored in Lugol's solution has been developed and tested. This method permits studies of the long term trends in the ultrastructural morphological changes associated with changing water conditions. The morphological features of the ultraplankton have also been studied in a cooperative effort with the Great Lakes Limnology Laboratory. This study has revealed some new characteristics of small algae, not demonstrable in light microscopy, that can be used as an aid in identification of species (Figure 8). There are indications that there are new species in Lake Superior that have not been reported previously.

The staff of the Electron Microscope Laboratory have been actively involved in organization of several workshops and seminars outside NWRI dealing with the topic of analytical electron microscopy.

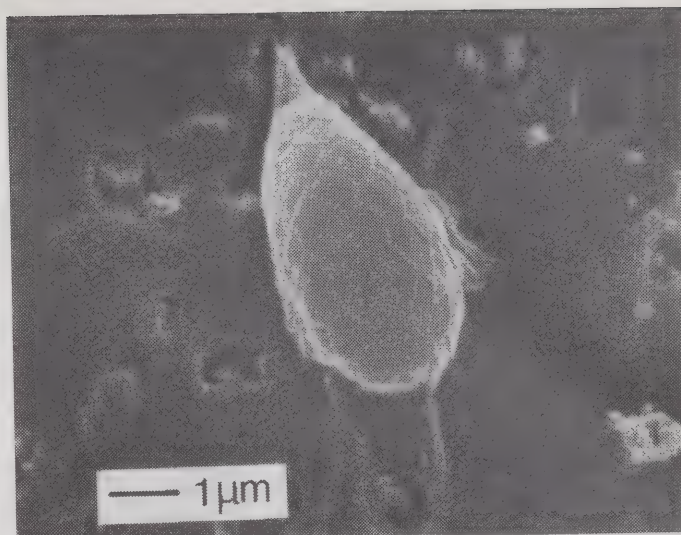


Figure 8 Morphological features of ultraplankton; electron micrograph of small algae



## ENVIRONMENTAL CONTAMINANTS DIVISION







**Table 2 Great Lakes open water radionuclide levels - 1979**

Lake	Average Concentration in pCi/l	
	Sr	Cs
Superior	0.50 $\pm$ 0.03	0.045 $\pm$ 0.006
Michigan	0.83 $\pm$ 0.06	0.035 $\pm$ 0.006
Huron	0.78 $\pm$ 0.05	0.027 $\pm$ 0.006
Erie	0.83 $\pm$ 0.05	0.017 $\pm$ 0.005
Ontario	0.88 $\pm$ 0.05	0.030 $\pm$ 0.006

**Table 3 Cs in Great Lakes fish - 1979**

Lake	Species	Average Concentration in Fresh Fish
		pCi/l
Erie	Coho Salmon	31 $\pm$ 2
	Rainbow Trout	37 $\pm$ 2
Ontario	Lake Trout	52 $\pm$ 2

## TOXIC SUBSTANCES SECTION

### Ecosystem Studies

The experimental aspects of the study in which in-ground ponds were treated with either oil or oil plus dispersant were completed this year. This experiment was initiated to ascertain the fate of both the added materials and their effect on the indigenous biota in the ponds over an extended period of time. A report on the fate of the oil and the oil plus dispersant in the ponds has been completed. The major findings concluded that the dispersant was not effective in solubilizing the oil, that there was no effect by the dispersant on the distribution or chemistry of the oil and its residues which were found primarily in the sediment and that the amounts of the oil found in the sediments of the oil-dispersant treated ponds were 50% less than found in the oil-treated pond. Certain aspects of the biota were affected by treatment, with the effects being greatest in the oil-dispersant treated ponds. Bacterial populations were generally constant and not different from the control, but the treating agents caused shifts in the populations. Zooplankton populations were reduced in the oil-treated pond and eliminated in the oil-dispersant ponds. Attached algae were most abundant in the oil-dispersant treated pond. These effects persisted only until spring thaw of the year after treatment when the populations returned to levels similar to the control pond.

Another series of pond tests were designed to investigate the effect of 2,4-D (amine and butoxyethyl ester) on *Myriophyllum spicatum* (Eurasian Milfoil). Six large in-ground ponds were installed on land owned by the Hamilton Region Conservation Authority. These were lined and partially back-filled with dirt to provide a 0.5 m sediment layer and a 0.3 m layer on the sides. After enclosing the entire area with a fence, the ponds were filled with water to a depth of 2 m from a nearby trout pond. Large mobile bridges were constructed to provide sampling platforms. *Spiratum* shoots were planted in the sediment during October to acclimatize these plants to the conditions of the ponds prior to treatment. Monitoring of the ponds, both biologically and chemically, was commenced in January.

The fate of hexachlorobenzene (HCB) in a flow-through model ecosystem containing water, sediment, algae, fish, snails and

ascella was studied in a joint study with GLBL. Radiocarbon labelled ( $^{14}\text{C}$ ) HCB and unlabelled HCB (1:100) was added in the form of a sediment at two levels (10 and 100 ng/day) for 32 days followed by 32 days of depuration. Analyses of system component were completed. Interpretation of data is proceeding.

Sediment cores were collected from the Bay of Quinte sectioned and analyzed for chlorophenols and chlorobenzenes. Pentachlorophenol (PCP) showed a rapid decrease with depth in the sediment from > 50 ng/g at 0-2 cm to < 5 ng/g at 10 cm. Some evidence for reductive dechlorination of PCP was observed. HCl levels were low (< 5 ng/g) and no significant pattern was observed due in part to the near detection level quantities.

The study on the distribution and transformation of fenitrothion [0,0-dimethyl-0-(p-nitro-m-tolyl) phosphorothionate] in aquatic environments was completed in 1979. This chemical is very heavily used in Atlantic Canada to control the spruce budworm. Fenitrothion concentrations in water, suspended solids, and sediment fell below detectable levels two days after a test pond had been sprayed. Only two degradation products of fenitrothion were identified in water and sediment, and both are generally believed to be far less toxic than fenitrothion, and persist less than four days. An hitherto unexpected pathway accounting for the disappearance of fenitrothion was discovered: the direct evaporation of fenitrothion from surface slicks when its formulation sprayed on water. This may be the major pathway of fenitrothion's disappearance or degradation in the aquatic environment.

During 1979, a study was started on the fate of organotin compounds in natural waters.

### Behaviour of Contaminants

A long-term project on structure-activity correlation of environmental contaminants commenced during the year. Data is being assembled on a wide variety of physical-chemical properties and the biological effects on several aquatic and mammalian species. This is intended to allow the development of relationships based upon empirical and theoretical grounds; toxicity, accumulation and persistence will be particularly examined for predictability.

A standard procedure and a new apparatus for determining the relative persistence of both water soluble and water insoluble organic compounds under various laboratory environmental conditions has been developed. The degradation test system is based on the measurement of the primary biodegradation rates of substances in cyclone fermentors under aerobic and anaerobic conditions, with or without co-metabolites. The biocides, fenitrothion and 2,4-D, were tested in the system and the calculated relative persistence agrees well with the published field data. Other substances tested in connection with the OECD Chemicals Program were aniline, p-nitrophenol, Marlon A and TPBS.

A field method for determining the chemical and biological activity of sediments was developed and its applicability to environmental sediment samples was examined by using replicate samples from Hamilton Harbour, Bay of Quinte, Batchawana Bay and Thunder Bay. The test is easily applied, is reproducible, and offers promise as a method of identifying different types of reducing activities in the sediments. It is being further evaluated on a large scale on sediments of Lake Huron.

A test system (flow-through chemostat) was developed for bioaccumulation studies, and testing with DDT using radiocarbon-labelled material has begun. The system will be used to compare partition coefficients on living algae species with those indicated by solubility and by octanol-water partition coefficients. Preliminary results indicate that a change to a turbidostat would offer advantages over a chemostat. Work is continuing.

### Metal Speciation

Differential pulse polarography has been found to be suitable for studying the electrochemically labile complexes of Fe, Mn, Zn, and Cu associated with relatively uncontaminated sediments from the Eastern Basin of Lake Ontario. These labile metal forms include inorganic and organic complexes but not metal ions adsorbed onto colloidal hydrated oxides or clay minerals. The first three elements exhibit well resolved peaks; the Cu polarogram consisted of a broad wave resolvable on titration. Recoveries of added metals were quantitative for the four metals.

In the process of speciation investigation, it was found that Amberlite XAD-4 and XAD-8 resins effectively sorb inositol hexaphosphate from lakewater. This compound is regarded as an important constituent of naturally-occurring dissolved organic matter and previous work indicates it binds strongly to transition metals.



A procedure which avoids the use of perchloric acid has been evaluated for determining total metals in suspended and bottom sediments. This aqua regia and peroxide oxidation method yields more accurate analytical results because potential losses of elements such as Cd and Pb due to volatility are avoided. In addition, the use of peroxide in this procedure preserved the Cr as Cr(III) rather than Cr(VI) in which form as much as 10% may be lost in procedures relying on perchloric acid.

Methylation of Pb(II) in sediments through the carbonium  $\text{CH}_3^+$  mechanism has been experimentally established by the use of  $\text{CH}_3\text{I}$ , both in chemical and biological systems. A survey on the occurrence of tetraalkyllead compounds in fish (107 samples), water (32), vegetation (44), and sediment (50) has also been completed. About 20% of fish showed the presence of tetraalkyllead. It has been experimentally shown that fish can concentrate  $\text{R}_4\text{Pb}$  compounds from water with accumulation factors up to 934 being observed for whole fish.

Preliminary experiments indicated that both Sn(II) and Sn(IV) compounds are methylated (or further methylated) in lakewater sediment systems. Comparative toxicity study with various Sn compounds on freshwater algae showed that toxicity is related to the length of the carbon chain and to the oxidation number of Sn. Toxicity decreased in the following order:  $\text{Bu}^3\text{Sn}^+ > \text{Pb Sn}^+ > \text{Me Sn}^+ > \text{Me Sn}^{++} > \text{Sn(IV)} > \text{Sn(II)}$ .

### Identification of Contaminants

Water samples from over 100 stations were analyzed for Freon 11, Freon 12, chloroform, carbon tetrachloride, and trichloroethylene. In general, the concentrations of such compounds were found to be in the 10 to 100  $\text{ng}\cdot\text{l}^{-1}$  range. Chloroform and Freon 11 concentrations were relatively uniform throughout the lake and Freon 12 levels were highest in the eastern basin. The concentrations of carbon tetrachloride and trichloroethylene appeared to be related to point-source discharges along the south shore of Lake Erie.

Point source studies were commenced to ascertain the suitability of several sites for analytical assessment studies of industrial effluents. Approaches to be evaluated are to be multidisciplinary and the locations to be investigated involve an industrial dump seeping into a small stream, a direct discharge of industrial process water to a river, and a before and after study of the impact of a heavy industry coking plant into a lake system.

The use of XAD resins for the *in situ* collection of rain samples was commenced. A large ( $2\text{ m}^2$ ) sampler lined with teflon was employed. Samples were collected on an event basis and the resin extracts will be examined for previously undetected organic substances. Plans are underway for development of a wetfall only, automatic sampler utilizing the resin collection principle.

## WATER CHEMISTRY SECTION

### By-Products of the Chlorination of Natural Waters

Drinking waters are usually disinfected with chlorine prior to use. Unfortunately, chlorine not only destroys bacteria, but also reacts with naturally-occurring humic and fulvic acids in the water to produce toxic by-products such as trihalomethanes (THM's). The concentration of THM's produced in the reaction depends on the amount of chlorine, humics and bromide in the water and also on the water temperature. We have measured the effect of these variables on the reaction rate under Canadian environmental conditions.

With a view to the removal of humic materials from the water prior to chlorination, a study was undertaken to find out the molecular weight of humics taking part in the THM reaction. We found that the most important precursors were low molecular weight fulvic acids. Only a small fraction of these compounds are removed by conventional water treatment processes, so new treatment methods may have to be used in locations where high THM concentrations are present in drinking water.

### Spectroscopic Techniques for Organic Analysis

Both fluorescence and UV-visible spectroscopic techniques have been used to quantitate humic materials in samples collected from across the country. Also, a resonance Raman procedure for carotenoids in plants has been developed, and has been used to quantitate carotenoid concentrations in several common species of freshwater algae.

## Water-Organic Partitioning and Spreading

Hydrophobic solutes, which include many toxic chlorinated hydrocarbons, accumulate strongly in biological lipids. This bioconcentration has been successfully correlated with the octanol-water partition coefficient of the solute (by Hansch and Leo, for example), but two related questions arose.

The first was whether octanol was a good model lipid; it probably is. The second, the subject of the present study, is whether partitioning is modified in the presence of the thin films of organic materials which form on the surface of the water.

The study comprises two experimental parts. The first of these is the physical characterization of synthetic two- or three-component surface films by means of a Langmuir film balance. The resulting surface tension-area plots are analogous to pressure-volume plots for gas mixtures and indicate to what extent the films deviate from ideal behaviour. The second part is the measurement of partitioning of a few model solutes between pure surface films and the underlying water.

### Naturally-Occurring Dissolved Organics

Naturally-occurring organic compounds are found in waters throughout Canada at levels that vary from 3 to 25  $\text{mg}/\text{l}$ . In a previous study, it was shown that, for many lakes and streams, most of the dissolved material falls under the operational definition "fulvic acid". Recent research has suggested that this material may have a greater role in ecological processes than previously supposed. In this study, we examined the natural organics for a drainage basin comprised of a forested stream, a shallow reservoir (which had a muskeg region at one end and discharged over a weir at the other end), a small town with a sewage plant, and a large reservoir discharging subsurface water. Levels of organic compounds were monitored on a bi-weekly basis. It was discovered that, for this drainage system, high levels of organics occurred twice per year, once in the spring and once in the fall. Since these levels coincided with increased nutrients from runoff, it was inferred that most of these organics were terrestrial in origin. Although both reservoirs were highly eutrophic and the shallow reservoir supported dense growths of aquatic macrophytes, neither reservoir significantly increased the dissolved organic carbon levels in the stream. Similarly, a very dense growth of *Myriophyllum spicatum* downstream of the sewage plant had little effect on the levels of dissolved carbon in the stream. Our conclusions are that the most significant input of dissolved carbon for this stream was runoff and leachate from surrounding lands, implying that decaying terrestrial vegetation is the principle source of dissolved carbon for this system.

### Aquatic Photochemistry

Work continued on the direct sunlight photochemistry of the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) and it was established that photodegradation of this substance is a significant process in the environment. A study using scavengers was undertaken to establish whether dissolved, naturally-occurring organics present in Canadian waters produced significant levels of oxidizing species when illuminated with visible light. Using scavengers specific for superoxide radicals, we were unable to detect any reaction and concluded that superoxide radicals were not being produced. Similar work with scavengers showed that singlet oxygen is produced when natural waters are irradiated with sunlight. Work is continuing to quantify singlet oxygen production and to examine its role in the photodecomposition of organic pollutants in natural waters.

The ability of organic material in water to photosensitize the oxidation of the herbicide, 2,4-dichlorophenoxyacetic acid (2,4-D), varied with molecular weight. Although the higher molecular weight fractions were less efficient photosensitizers, they were present in such high concentrations that they were the most significant natural photosensitizers. A paper outlining the potential uses of semiconductor photochemistry in advanced wastewater treatment was prepared and delivered. Another paper was published, showing that suspended sediments did not act as photosensitizers but merely screened out light and decreased the rates of photoreactions in solution.



## HYDRAULICS DIVISION





The Hydraulics Division undertakes research of natural phenomena related to the physical aspects of water and sediment. For its objective, the Division has interpreted the general objective of the Inland Waters Directorate as:

"To advance, apply and communicate scientific and engineering knowledge and understanding of all aspects of inland waters for the use of planners, engineers and managers of such resources throughout Canada."

In order to pursue this objective the Division undertakes national programs in applied and basic research related to hydraulic, fluid mechanic, hydrologic, geophysics and geologic processes as they apply to fluvial, lacustrine and man-made environments. The activities are:

- (i) To undertake - directly or by contract - applied and basic research into problems related to environmental processes, the optimum development of resources, the assessment of proposed changes in the environment and the protection of desirable environmental features.
- (ii) To develop mathematical models for descriptive and predictive purposes.
- (iii) To provide consultative services, information, technical reports, and expertise on environmental problems for government agencies, for the private sector, and for universities.
- (iv) To provide services in the calibration and testing of instruments for clients from government, private, and university sectors.
- (v) To undertake - directly or indirectly - scientific and engineering investigations or studies of specific problems brought by clients within the Department of the Environment or other departments.
- (vi) To provide and encourage a stimulating environment and facilities for government and university researchers and to disseminate information and research reports and results through publications, seminars and conferences.

These activities are shared by three operational Sections and an Administrative Unit.

## ENVIRONMENTAL HYDRAULICS SECTION

The Environmental Hydraulics Section concentrates on three main areas of research, namely: river processes, ice and water interactions and urban water resources. In river processes, the mixing as well as the mass and heat exchanges taking place in open-channel flows are investigated. Development of models which can predict the mixing of effluents and the response of rivers to man-made changes are of prime concern. The mechanics of ice-jams, the conveyance capacity of an ice-covered river and the effects of frazil ice on the flow are all important questions which have to be addressed. There is also an interest in techniques for control and recovery of oil in ice-covered waters. In the urban water resources area, emphasis is placed on the development and verification of models for urban runoff quantity and quality. The effect of urbanization on urban drainage is investigated in order to improve management and design of stormwater systems.

### Bed-Load Discharge Coefficient for Migrating Dunes

A bed-load discharge coefficient was obtained by using dimensional analysis and laboratory experiments conducted in a rectangular flume. The coefficient value was found to depend on the steepness of the bed form and relative sand grain size. The results showed that the bed-load coefficient depends on two types of dune conditions:

- (i) When the dunes are flat, the bed-load coefficient value is affected by sand grain size.
- (ii) When the dunes are steep, the bed-load coefficient value is affected by dune steepness.

### Calibration of Bed-Load Samplers

Basic analytical considerations showed that a calibration equation for a given sampler might contain as many as five independent dimensionless variables and the effects of each must be determined experimentally. Limited data from calibration of a basket sampler has shown that there is a strong likelihood that the sampling efficiency of a bed-load sampler may be determined by a single dimensionless parameter called the TRAP NUMBER. The form of the general calibration equation suggests that it may be desirable to review field sampling procedures. Recommendations were made to conduct tests to determine the relative importance of the independent variables in the general calibration equation for different sets of conditions.

### Flow Separation Over Dunes

For the purpose of understanding of the formation of sand waves, experiments were carried out in a rectangular flume to measure the length of the flow separation under different flow conditions, dune steepness and sand grain size. It was found that:

- (i) As the dune steepness increases for a given value of sand grain roughness, the separation length decreases.
- (ii) When the sand grain roughness increases, the separation length is reduced.
- (iii) The effect of sand grain roughness on flow separation is greatest when dunes are flat and decreases as dune steepness increases.

### Terminal Velocity for Optical Turbidity - Temperature Profiler

The Hydraulics Division was requested by the Engineering Section of the Scientific Support Division at the National Water Research Institute to determine the terminal velocity of an instrument package called "Multiband Transmittance Temperature Profiler". The profiler gathers vertical temperature profiles and turbidity data while dropping in "free fall" from water surface to lake bottom. Two descent modes were considered:

- (i) The profiler descends with its longitudinal axis parallel to direction of travel,
- (ii) The longitudinal axis is perpendicular to the direction of travel.

The terminal velocity of a free falling body was derived and recommendations were made regarding the required mass of the instrument package.

### Calibration of Velocity Meter for Flow Measurements in Peat Bogs

The Hydraulics Division was requested by the Engineering Section of the Scientific Support Division at the National Water Research Institute to calibrate a flow meter called "Thermo-Velocity Probe". Calibration was conducted in a specially-fabricated set up for this flow meter. A report of the results is under preparation.

### Modelling Transverse Mixing in Natural Streams

A numerical model was developed to calculate the spreading of a conservative tracer in natural streams. The model equations are based on a curvilinear-orthogonal coordinate system. The equations were greatly simplified through the introduction of a transverse coordinate based on the stream-tube concept, making it possible to include the effects of changes in cross-sectional properties and stream curvature without having to measure the transverse velocities.

The model was verified using dye source test data observed from the Grand River near Kitchener, Ontario. The concentration distributions resulting from a dye source were correctly simulated. Data for the transverse dispersion coefficient for natural streams were analyzed and a curve for estimating this coefficient is presented.

### Effect of Ice Cover on Stream Flows and Vertical Mixing

Study on the effects of ice cover on the stream flows and vertical mixing characteristics was conducted. By using the "K-E" turbulence model to describe the turbulence structure in channel flows, a computer program was developed to calculate the depth, velocity distribution and the turbulent kinematic viscosity distribution for two flow conditions, with same discharge, bed slope and bottom roughness.

The two flow conditions are:

- (i) Free surface at the top, and
- (ii) Ice cover of given roughness.

The results are then applied in the mass transport equation to simulate the concentration distributions resulting from sources located at different depths in the flow. The results gave a clear indication of the effects of ice cover on the flow properties and the vertical mixing characteristics.

### Improved Design of Road Drainage

As requested by the Ministry of Transportation and Communications, the Hydraulics Division conducted a study of hydraulic capacities of selected sewer inlets. In the first phase of the study, hydraulic capacities of inlets installed on a continuous grade were investigated. The observed experimental data were used by the Ministry to develop a new design procedure for spacing of road drainage inlets.

The second phase of the study started in late 1979. Investigations of inlets in a road sag have been completed. Other tests to be undertaken in the second phase include the development of new inlet grates with improved capacities and development of a new ditch inlet.

### Field Study of Urban Runoff

The field study of urban runoff in the Malvern Catchment was continued in 1979. During the field season spanning from April to November, a large number of rainfall/runoff events were observed and analyzed. The collected data will be used in the ongoing long-term study of urban runoff.

### Rainfall Inputs for Urban Runoff Simulations

In continuation of earlier studies, analysis of various rainfall inputs for urban runoff simulation was conducted. Using a long rainfall record, historical storms likely to produce lower runoff peaks were identified when compared to synthetic design storms. The preparation of guidelines for selection of rainfall inputs for urban runoff simulations was started.

### Sewer Junction Study

The first phase of the study of energy losses at sewer junctions was completed. This phase dealt with both open-channel and pressurized flow through straight-flow-through junctions. Energy loss coefficients were established for a range of pipe slopes and selected junction geometries.

### Waterford River Basin Study

Urban development in the Waterford River Basin caused a number of water resources problems including flooding and deterioration of water quality in the Waterford River. To find remedies for these problems, an urban hydrology study of the basin was proposed. The Hydraulics Division was invited to participate in preparing a plan for such a study. In cooperation with IWD, Atlantic Region, and the province of Newfoundland, an updated plan was prepared for the study of the Waterford Basin, and the start of the study in early 1980 was recommended.

### Field Studies of River Ice Jams and Flooding

A field study program to study river ice jams and flooding was initiated this year. This field study program, emphasizes collection of quantitative data needed to address both deterministic and statistical aspects of river ice breakup and jamming phenomena. A reach at the lower Thames River in Southern Ontario was selected for monitoring ice conditions in winter and hydrometric observations in summer. A field operation plan was prepared. The 1979/80 winter monitoring has already commenced with several fall jams observed and documented. Contact and cooperation with other agencies interested in jamming problems were also established.

### Development of Frazil Ice Instrument

The laboratory version of the frazil ice instrument development is close to completion. Some hardware electronic problems have yet to be rectified. Close cooperation with Ontario Hydro has been established to debug some of the electronic problems.

### Ice-Oil Boom development

All the necessary laboratory experiments on the finned ice/oil boom have been satisfactorily completed. A report on the results is under preparation.

### Ice-Cover Resistance of Beauharnois Canal

The analysis of the Beauharnois Canal hydraulics data has been completed. The results revealed that the variation of the Chezy C of the canal is a function of different hydro-meteorological parameters. A report will be prepared in 1980.

## SHORE PROCESSES SECTION

This section conducts research in three main areas: surface waves; shore resources; shore dynamics. Studies of surface waves concentrate on air/water interaction such as the generation and propagation of waves. Shore resources and geological influences are documented by conducting technical surveys and interpretation of nearshore sediments, mainly in the Great Lakes. Studies in shore dynamics investigate nearshore waves and currents, nearshore sediment movements, and mechanisms of bluff behaviour. In addition, coastal engineering work is undertaken, such as investigations of wave agitation problems in harbours, and the determination of the nature of remedial structures needed to reduce the waves inside the harbours.

### Nearshore Sediment Survey

The major effort in nearshore survey work during 1979 was the detailed mapping of the sediments of the north shore of central Lake Erie in support of a DPW investigation of shore erosion. This has resulted in improved definition of the extent, thickness, morphology and texture of postglacial deposits for the Port Glasgow to Long Point reach.

Data reports were compiled to answer requests for nearshore data at Owen Sound, Wasaga Beach, Fifty-Mile Point, western Lake Ontario and Lake Huron. In anticipation of similar requests, work has begun on a series of data reports of all available field and laboratory data for samples collected as part of the nearshore survey program of the lower lakes.

### Time-Lapse Camera Studies

The underwater time-lapse camera system has been improved by the addition of an automatic flash unit which extends the range of light conditions in which proper exposure can be obtained. On completion of laboratory and field testing, the system was installed in Lake Ontario opposite Stoney Creek, Ontario for an extended winter mission of recording the effects of storms and ice on the erosion of the nearshore slope.



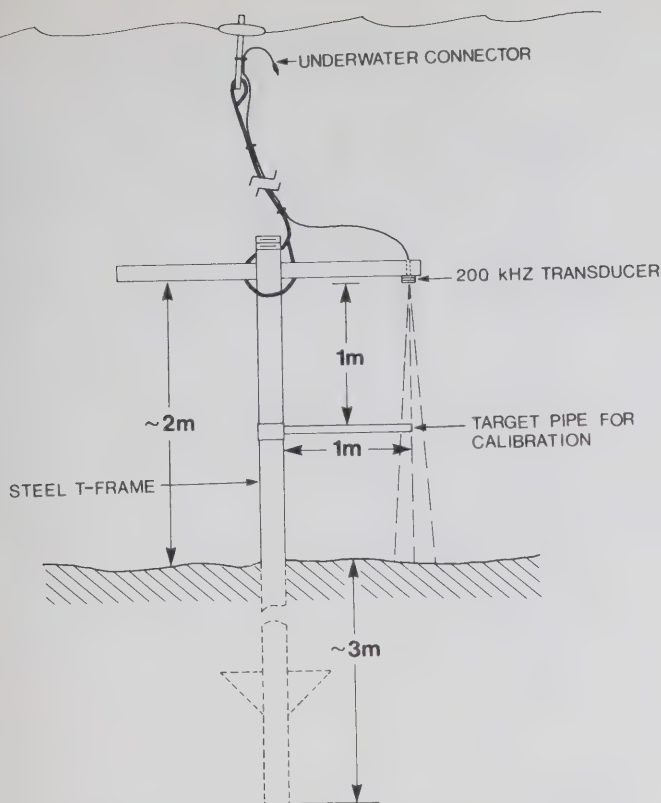


Figure 1 Fixed transducer system for nearshore changes in morphology

#### Fixed Transducer Measurements of Nearshore Profile Change

The fixed transducer system (Figure 1) developed for remote measurement of small-scale changes in nearshore morphology has been used this year in a study of profile change at Van Wagner's Beach, Hamilton, Ontario. A T-shaped array of transducers was installed in the depth range of 1-7 m and monitored at weekly intervals from mid-August 1979 to mid-January 1980. Results show small-scale (0-3 cm) reversible changes in profile elevation during the summer and early fall followed by major changes involving displacement of the offshore bar during the falling water levels and increased storm activity of the early winter.

#### Littoral Drift Experiment, Lake Ontario

The field measurements of the suspended sediment concentration, flow velocities across the surf zone at Van Wagner's Beach were continued during 1979. A total of four separate experiments (seven individual traverses of the zone) were conducted during the spring and fall field seasons. These measurements add to the growing data base collected at the site, and analysis of these data is being accelerated to permit the release of the preliminary results in published form during 1980.

Further detailed analysis of the data has revealed that the amount of sediment transported as suspended particles during periods of wave activity ranges as high as 86 metric tonnes (approximately  $54 \text{ M}^3$ ) per hour. (This figure replaces the earlier estimate shown in the Hydraulics Research Division (HRD) 1978 Annual Report of 700 tonnes/hour and is in better agreement with results obtained by other researchers in this field.) Such a transport rate probably represents the major portion of the total littoral drift during that particular storm.

#### Field Measurements of Wave Height, Direction and Currents

The field measurements of wave height and direction just offshore of the surf zone and currents in the surf zone from fixed sensor arrays were continued in 1979. The ducted impeller current meters continued to be plagued with fouling problems. The wave staffs operated successfully. Data are being analyzed in conjunction with the sediment data, and the preliminary results will be released in 1980.

#### Fifty-Mile Point Landfill Impact

In a report documenting the long-term erosion rates in the vicinity of the protruding landfill (1978 HRD Annual Report), the total littoral transport was estimated between 2000 and  $3500 \text{ M}^3/\text{year}$  (average from 1934-73). This compares well with observed trapping rates at the landfill structure of  $3670 \text{ M}^3/\text{year}$  from August 1977 to November 1978.

Monitoring of the recession and accretion patterns around the structure is continuing.

#### Port Burwell Shoreline Evolution and Modern Recession Study

At the request of the Department of Public Works, two reports were drafted during 1979. One of the reports featured a reconstruction of the rate of evolution of the central shoreline of Lake Erie during the 12,000 years of postglacial time, based on data from existing literature and inference therefrom. In the other report, modern-day recession rates (1935-1979) were calculated for the reach from Port Glasgow to Clear Creek.

#### Stability of Terrafix Blocks

Tests to determine the effectiveness of armour block systems to withstand wave attack were completed for Terrafix Erosion Control Products Inc. In all, four block types were tested on three slopes under attack from waves of four different periods. The influence of the type of subgrade material and the filter cloth were examined. Most of the tests utilized regular waves, but a short series of tests were run using irregular waves so that the regular wave height causing failure could be correlated to the irregular wave height causing failure.

#### Geotechnical Studies of Eroding Bluffs

Geotechnical study of the 31.5 km long shore between Colchester South and Gosfield South Townships, western Lake Erie, has been completed. This study was undertaken as a part of the Canada/Ontario Shoreland Management Study Team. Results of the study were released in an NWRI Unpublished Report, December 1979. Information presented in the report include stratigraphy, geotechnical properties, bluff slope stability, average wave power at breaking point, volumetric recession rates for each principal size class and an estimate of sand volumes in the littoral zone.

#### Shoreline Stratigraphy

The recession rates of bluff-type shoreline between two major sand spits, Point-aux-Pins and Long Point in Central Lake Erie are among the highest measured in the entire Great Lakes area. The bluff recession (range 5 to 10 m/year in some locations) continues to be a pressing problem. A study was initiated to compile available information on shoreline stratigraphy and to prepare stratigraphic cross sections for this stretch of Lake Erie shoreline.

#### Port Burwell Pore-Water Pressures and Subsurface Movements Monitoring

Monitoring of pore-water pressures and subsurface movements at the Port Burwell study site, Ontario, continued throughout the year. Previous problems associated with the damage of vibrating-wire piezometers and electronic equipment caused by lightning surges did not occur this year, as a result of improved lightning surge arrestors and diverting techniques designed by the Engineering Services Section, NWRI. Data processing and plotting of the piezometric records continues. Topographic survey of the Port Burwell site was conducted in July 1979 by the Technical Operations Section.

Preliminary results indicated that the recession attributable to gully development has abated considerably compared with previous years.

#### Floating Tire Breakwater

The Floating Tire Breakwater (FTB) is a relatively new kind of breakwater. The FTB is constructed mainly of discarded car or truck tires. The FTB is worthy of consideration at locations

where the maximum fetch is less than 10 km. The FTB's outstanding feature is its low capital cost relative to other floating or bottom-resting breakwaters.

To meet the anticipated need for guidance in the use of FTB's, work has begun on the preparation of a comprehensive design and construction manual for two types of FTB:

- (i) The Goodyear FTB, and
- (ii) The Pole-Tire or Harms FTB.

This manual will include the latest research work and experience, determination of design waves for a selected FTB site, the size of FTB, use of construction materials and assembly. This manual should be useful for coastal or marine engineers as well as marina owners or other engineers. The anticipated completion of this manual will be early in the 1980/81 fiscal year.

#### Cobourg Harbour Model Study

A fixed-bed physical model of Cobourg Harbour, Lake Ontario was used to investigate wave agitation in the harbour. The investigation was undertaken to define the wave climate in the existing harbour and to determine the nature of remedial structures needed to reduce the significant wave height to less than 0.3 m during the boating season. This study was undertaken for the Small Craft Harbours Branch, Ontario Region, and was done in cooperation with Public Works Canada. Results of the study were presented in an NWRI Unpublished Report, October 1979.

#### Directional Spectra of Wind-Generated Water Waves

As part of the W.A.V.E.S. (water/air vertical exchange studies) program, field and laboratory measurements of wave-number frequency spectra of wind-generated waves were gathered in 1976 and 1977. The analysis of the "steady" cases has been completed. There were 91 cases (84 in the field and seven in the laboratory).

There are three main aspects of the wave-number frequency spectrum of wind-generated waves which find practical application in fields such as wave forecasting and coastal engineering. These are:

- (i) Dispersion Relation (phase speed and group velocity),
- (ii) Directional Characteristics (mean directional and spreading), and
- (iii) Frequency Spectrum (distribution of energy with frequency).

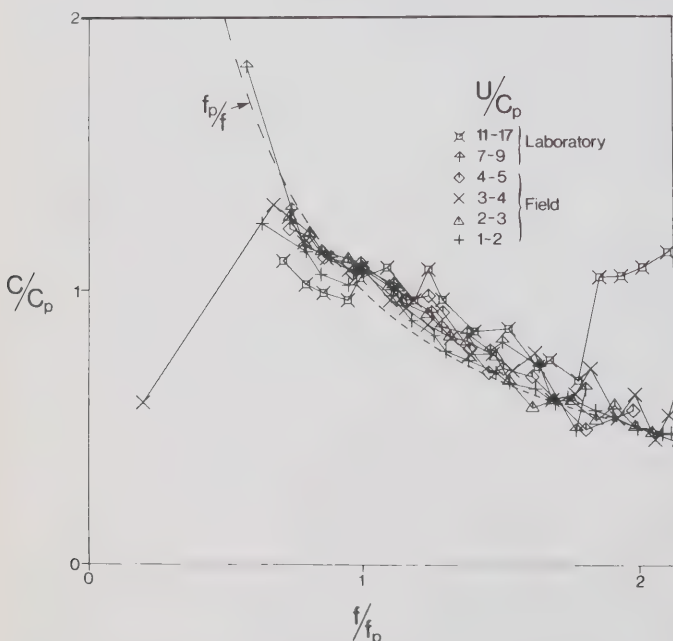


Figure 2 Normalized phase speed vs normalized frequency

A Summary of results in the above three categories follows:

- (i) Dispersion Relation - The small amplitude dispersion relation for deep-water waves ( $\omega=\sqrt{gk}$ ) is an adequate description of field waves and of laboratory waves except when the ratio of wind speed to peak phase speed  $U/C_p$  exceeds 9. In Figure 2, a summary of the observed phase speeds and the theoretical curve ( $C=g/\omega$ ) illustrates this point. In the figure, the observed (symbols) and theoretical (dashed line) phase speeds are normalized by the theoretical value at the peak. The data are grouped by  $U/C_p$ , the ratio of wind speed to phase speed at the peak of the spectrum and plotted against the ratio of frequency to the frequency of the peak of the spectrum.
- (ii) Directional Characteristics - The mean wave direction was found to differ from the steady-state wind direction by up to 50 degrees in areas of strong fetch gradients. A method of predicting the mean wave direction from the wind direction and the fetch distribution has been developed. The angular spreading of the waves at each frequency has been parameterized in terms of the inverse wave age  $U/C$ .
- (iii) The Frequency Spectrum - The rear face or "equilibrium range" of both laboratory and field spectra indicate that an  $f^{-4}$  dependence is a better description than the conventional  $f^{-5}$ . A suitably modified JONSWAP style spectral shape describes both very young laboratory waves and Pierson-Moskowitz style fully-developed spectra.

#### Wave Direction Buoy

A buoy, developed by Hermes of Halifax and modified to include self-recording, was deployed in the Central Basin of Lake Erie during August and September, 1979. The buoy measures the six degrees of freedom of its motion using accelerometers, a compass and pitch-roll gyroscope. Twenty minute recordings were made every eight hours from which spectral wave height and direction information will be derived for verification of wave prediction models - in particular the NWRI-developed model. The wind input to the models will be obtained from five meteorological buoys distributed over the lake in support of another experiment at NWRI.

### TECHNICAL SERVICES SECTION

The major functions of the section are:

- (i) The general maintenance and operation of the Hydraulics Laboratories.
- (ii) The provision of technical support to the Environmental Hydraulics and Shore Processes Sections to assist scientists and engineers with their research studies.
- (iii) The calibration and testing of current meters and other hydrometric equipment in the tow tank and the cold environmental testing chambers by the National Calibration Service.

The section is "Service" oriented and is divided into four units which interact as the need arises to perform the necessary services.

#### Laboratory Services

This unit provides support in such areas as woodworking, light machine shop, electronics, and photography, in the maintenance, modification and design of laboratory equipment.

#### Hydraulics Support Unit

The staff of this unit are assigned to scientists or engineers of the Environmental Hydraulics Section for setting up experiments, recording and analyzing data.

#### Shore Processes Support Unit

This unit operates geotechnical sedimentological and X-ray laboratories in support of ongoing research within the Division as well as service to outside agencies.

#### National Calibration Service

Calibration of current meters and other special tests on hydrometric equipment are performed for federal and provincial agencies and for clients in the private sector.

**ENGINEERING AND COMPUTING SUPPORT DIVISION**





The Engineering and Computing Support Division is responsible for providing specialized services to the Canada Centre for Inland Waters (CCIW), principally the National Water Research Institute (NWRI), including its Regional Offices. The services rely on highly skilled professions, crafts and trades related to engineering and computer science. Each year a resource plan is drawn up to allocate the services to certain studies being done in CCIW and NWRI. In 1979-80 the plan had 15 major goals besides the continuing services. The achievements can be grouped into five categories: Applied Research and Technology Transfer, Developments and Modifications, Installations, Calibration and Test Facilities' Improvements, and Regular Services. The following was accomplished by 31 people.

## APPLIED RESEARCH AND TECHNOLOGY TRANSFER

### Current Meter Comparison

In cooperation with the Applied Research Division and Technical Operations, a current meter comparison study was formed mid-fiscal 1976 to organize and execute a field experiment. The purpose was to compare at a single site a number of current measurement systems - some old, some new, and some under development - as a means of assessing confidence in their relative performance capabilities. In fiscal year 1977, the data from the experiment were processed and the comparison work was started. An intensive review of electromagnetic current sensor technology - including diagnosis of many previous applications of these sensors at NWRI was conducted. A polling of scientists was made to determine the development needs for future current measurement requirements.

The emphasis in this study has been placed on obtaining better estimates of data quality for water current measurements. Once the definition of the experiment requirements and the state of knowledge of the instrument response characteristics have been assembled, refined current measurement system models and instrument testing experiments can be developed effectively.

### Behaviour of Wind Direction Sensors

After the results were known from two previous studies on the behaviour of wind direction sensors mounted on separate buoys, a small study was done on the behaviour of three different wind vanes on a single, medium-sized buoy. One vane was the NWRI standard type, one was the buoy itself as it tends to orient with the wind and the third was a heavily damped wind direction sensor made up for the study. Intercomparison of the data, with the help of people from the Aquatic Physics and Systems Division, showed interesting results with some consistent differences in readings which are yet to be explained. Other anomalies have been explained and action will be taken to minimize their effect.

### Cooperative Program with Industry (COPI)

The Cooperative Program with Industry is patterned after the successful plan in the National Research Council, which transfers designs, inventions, processes and concepts to Canadian industry for their exploitation. COPI is now operated within the Department of the Environment. The National Water Research Institute was asked to contribute proven inventions which could be commercially valuable to industry. Engineering made six submissions of which four were accepted. They are the Medium Capability Buoy, Acoustic Marker, Stable Dissolved Oxygen Sensor and Light Weight Corer. As well, scientific authority was assumed on a fifth successful submission based on a new type of current meter. Liaison with industry is continuing and the contract for the buoy was completed successfully this year.

### Technology Transfer and Liaison

The Division organized and sponsored a workshop entitled "Federal Water Research and Surveillance Instrumentation Development". About 20 people from 10 federal government organizations attended the workshop to discuss related problems and solutions in instrumentation development.

## Contracts

Several contracts were completed this year with Canadian industry. They ranged from production and assembly to custom design. Standing offer agreements were entered into for items such as underwater cable production. The companies were given technical assistance to improve the product where necessary. Custom designs included special electromechanical cables for a buoy mooring and the prototype of a high-accuracy underwater temperature transducer.

## DEVELOPMENTS AND MODIFICATIONS

The following selection gives an indication of the calibre and scope of support given to the studies at CCIW. Many developments and modifications are not mentioned here, but were just as vital to the success of the studies they served.

### Automatic Arctic Winch Mechanism

The study of ocean currents in the arctic has become high priority as hydroelectric and petrochemical developments progress. Some of the data are best collected by profiling the water column when the sea is covered with ice. However, this can be dangerous if the ice cover breaks up. Therefore, an unattended profiler was developed in cooperation with Ocean and Aquatic Sciences (OAS). A winch mechanism (Figure 1) was designed and built to be compatible with the OAS controller and sonde. The system must be compact and of light weight because of arctic transportation restrictions.

### Bridge for Working over Ponds

Toxic substances and their influence on the biota of lakes and rivers are being studied in artificial ponds. The ponds are quite large and access to the whole pond for sampling and sowing was impossible without disturbing the pond. For this reason, a suitable supporting structure was provided by placing two sections of tower (commercially available TV antenna) side by side. Large diameter, pneumatic-tired casters are provided on both ends to move the bridge over relatively unprepared soft surfaces. The structure spans 12 meters and is sufficiently light and mobile to be readily pushed by two people over any one of the six ponds in the study area.

### Buoy to Support FTB Cables

In the past, the Fixed Temperature Profiler (FTB), which is a heavy, electromechanical cable and a data logging system, has been supported in the water column by a fibreglass Nun buoy. This buoy itself is heavy and susceptible to damage requiring extensive repairs.

A new buoy has been designed to minimize these problems. It consists of two concentric aluminum tubes welded together, the annular space between the tubes being filled with low-density, urethane foam. The central tube houses the data logger. Lead weights are placed at the bottom of the inner tube to adjust the buoyancy to suit the weight of the various lengths of the cable. The mounting of the cable to the bottom of the buoy has also been modified to minimize chafing and fatiguing the cables and give increased reliability.

### Camera for Wave Study

Whitecapping in waves is of interest because it indicates major shifts in the forms of energy in waves and wind. Therefore quantitative studies have been initiated as part of the air-water interaction studies, using a photologger system constructed by the Division. The system consists of a 16 mm camera, an automatic

exposure control, case heater, blower and timing circuitry, all of which are mounted in a weatherproof case. The water surface, as seen from the CCIW tower, is photographed with time, date and reference standards for colour and contrast. The system is connected to a control box by cables. All commands are generated by a shore-based computer which also services several other functions on the tower.

#### Centrifuge Improvements

Continuous-flow, ultra centrifuges are being used in the field to minimize the sample sizes being returned to CCIW. This technique has been quite successful for some time, but the centrifuges have been prone to damage. The case histories of these malfunctions were reviewed and this prompted the start of field-ruggedization work on the centrifuges. An operator's and maintainer's manual was written, and proper field transport cases, which include shock mounts, were provided. Techniques for rebalancing and aligning the centrifuge bowls were studied in order to minimize the down time and costs associated with equipment failures.

#### Computer Hardware Systems for Chemical Laboratory Automation

A minicomputer based system has been installed to acquire, process, store and report analytical results from over 375,000 chemical analyses done each year at CCIW. These results are produced by a variety of analytical laboratory instruments which include autoanalyzers, atomic absorption spectrophotometers, gas

chromatographs. A total complement of 30 instruments is connected to the computer for direct data acquisition. Manual entry of results is done through many computer terminals. A relatively simple system architecture is created through serial, digital, data-transmission techniques for all but four instruments. Standardized connectors in each laboratory allow mobility of both computer terminals and instruments. Currently 13 computer terminals enable users to access the computer for data uptakes and synopses. A bar-code reader is incorporated to help the operators in recording data and accessing the computer quickly. The system carries the acronym AWQUALABS for Automated Water Quality Analytical Laboratory Systems.

#### Domes for Measurement of Gas Exchanges in Littoral Ecosystems

Transparent plastic domes have been successfully used for measuring oxygen exchange in lake sediments. Based on this experience, a simple trap was designed for the measurement of nitrogen fixation by underwater plants (macrophytes) in the littoral zone. The trap consists of a thin-wall, acrylic hemisphere to which a skirt has been added for good isolation after the dome has been inserted into the lake bottom. Acetylene gas is fed to the dome through a tube from the lake surface. The gas bubbles up through the water inside the dome. A pump at the surface is used to keep the water inside the dome in constant motion. The lens of gas formed at the top of the dome is then sampled for estimation of nitrogen fixation by the plants within the dome. To avoid the need for diving, the apparatus is installed and retrieved from the surface by means of a rod which can be assembled in sections.

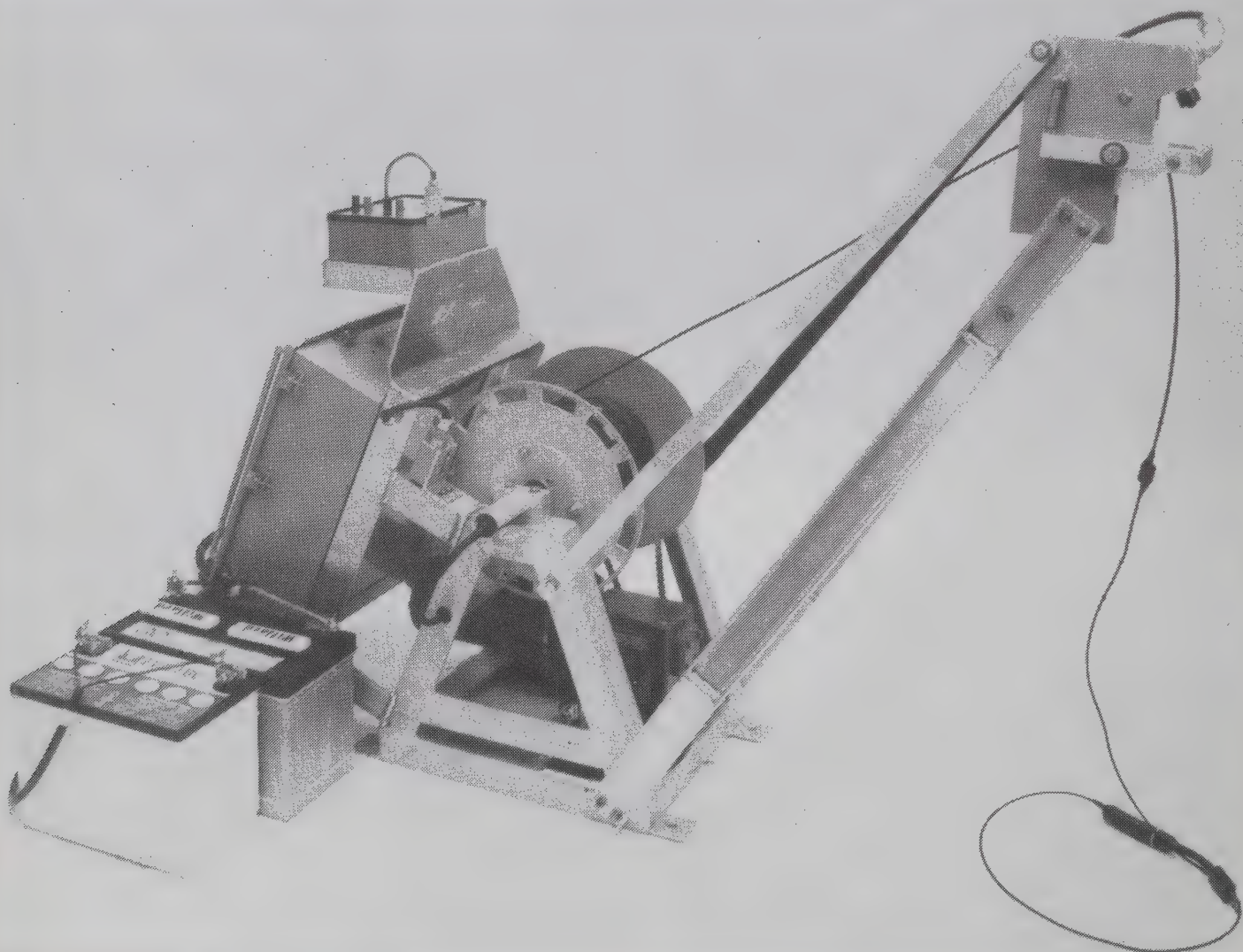


Figure 1 Automated arctic winch mechanism



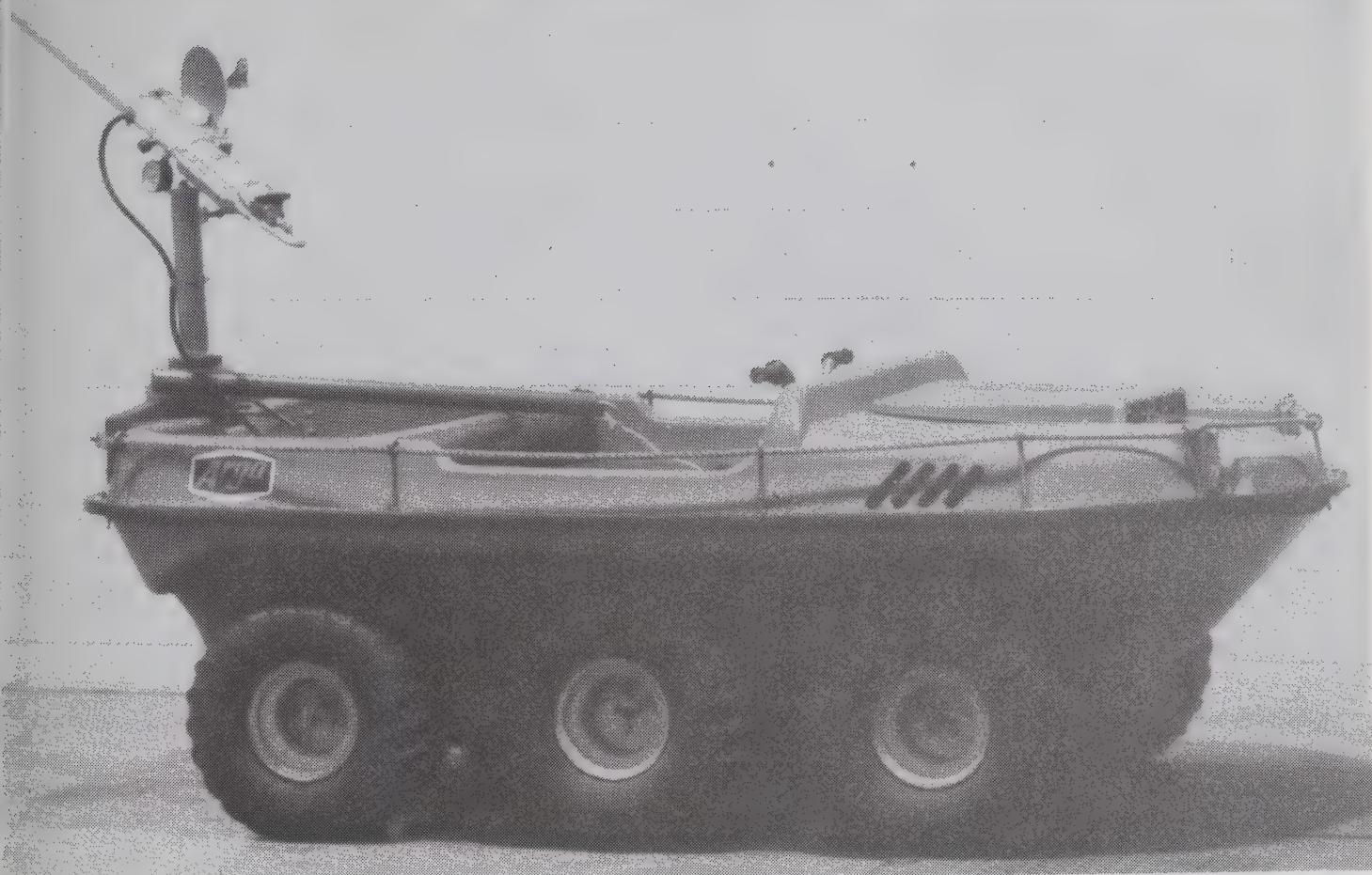


Figure 2 Drogue system for littoral zone

#### Drogu System for Littoral Zone

A system has been designed and built for tracking shore currents in the surf zone. The system has a launcher mounted on a vehicle (Figure 2). Special drogues which consist of orange tennis balls, are projected well out into the surf zone even against high winds. The balls are modified either to float with one-third of their diameter exposed, or to sink for a period of time and then return to the surface after dropping a weight. The time delay for releasing the weight is controlled by salt tablets which are glued between the weight and the ball.

The launcher is a muzzle-loading, compressed-air powered, single-shot cannon, mounted on an "Argo" all-terrain vehicle. The cannon can be trained in any azimuth, but it is normally operated at a fixed elevation, and the range is varied by changing the air precharge pressure. Ranges of about 50 meters into a gale can be achieved with the system.

#### Improvements to TROV

Anomalies in the earth's magnetic field can be quite severe, or the field can be very weak and cause magnetic compasses to malfunction. Since the underwater, unmanned, surveillance vehicle, Tethered Remotely Operated Vehicle (TROV), is to be used in locations having these effects, it was fitted with a gyrocompass unit. The unit was selected on the basis of low drift characteristics consistent with TROV's size, power and configuration.

To keep the subsystem simple, a special mirror and lens viewing arrangement provides the visual display for the operator, who monitors the system readouts with a closed-circuit television. The gyrocompass can be preset to a given heading (usually North) by remote control, prior to a surveillance run. The gyrocompass will maintain this preset bearing, and the heading of TROV can be monitored from a compass rose, on the TV monitor.

Other modifications and repairs were done to improve the performance of the TROV system. These are: welding of all fixed joints in the electronics chambers to eliminate leaks and structural weaknesses; paralleling of the air compensation cylinders for the ballast system to increase underwater endurance; building new camera and flash unit mounts and reworking the remote triggering system for the 35 mm still camera system; overhauling and reversing the umbilical cable to eliminate damaged portions; fabrication of propellor guards to avoid cables or debris being trapped in the propellers; reworking of the control servos to increase their reliability; and a general overhaul of the complete machine with Technical Operations personnel.

#### Logger for Anchor Station Substudy

The intensive Lake Erie studies required a logger to record and display on shipboard, the temperature and depth data from two separate sensor systems - a thermistor chain hung over the side of the ship and an electrobathythermograph (EBT).

The system was built up quickly from readily available subsystems. The controller was a desk-top computer. The EBT data were multiplexed through a Hewlett-Packard Multiprogrammer, then digitized with an integrating voltmeter. The thermistor chain's data were conditioned by a set of amplifiers and bridges built at CCW several years ago, then multiplexed and digitized by the multiprogrammer modules. The data were then assembled by the calculator and logged in computer-compatible format on half-inch magnetic tape. Except for some special wiring for the inputs, the only custom hardware was an interface between the calculator and the magnetic tape recorder. A back-up system consisted of a cassette-storage data logger which was wired in parallel with the thermistor chain inputs to the multiprogrammer.

The system itself (Figure 3) is a good example of how a relatively complicated system can be put together easily using the currently available modular hardware and desk-top computers.



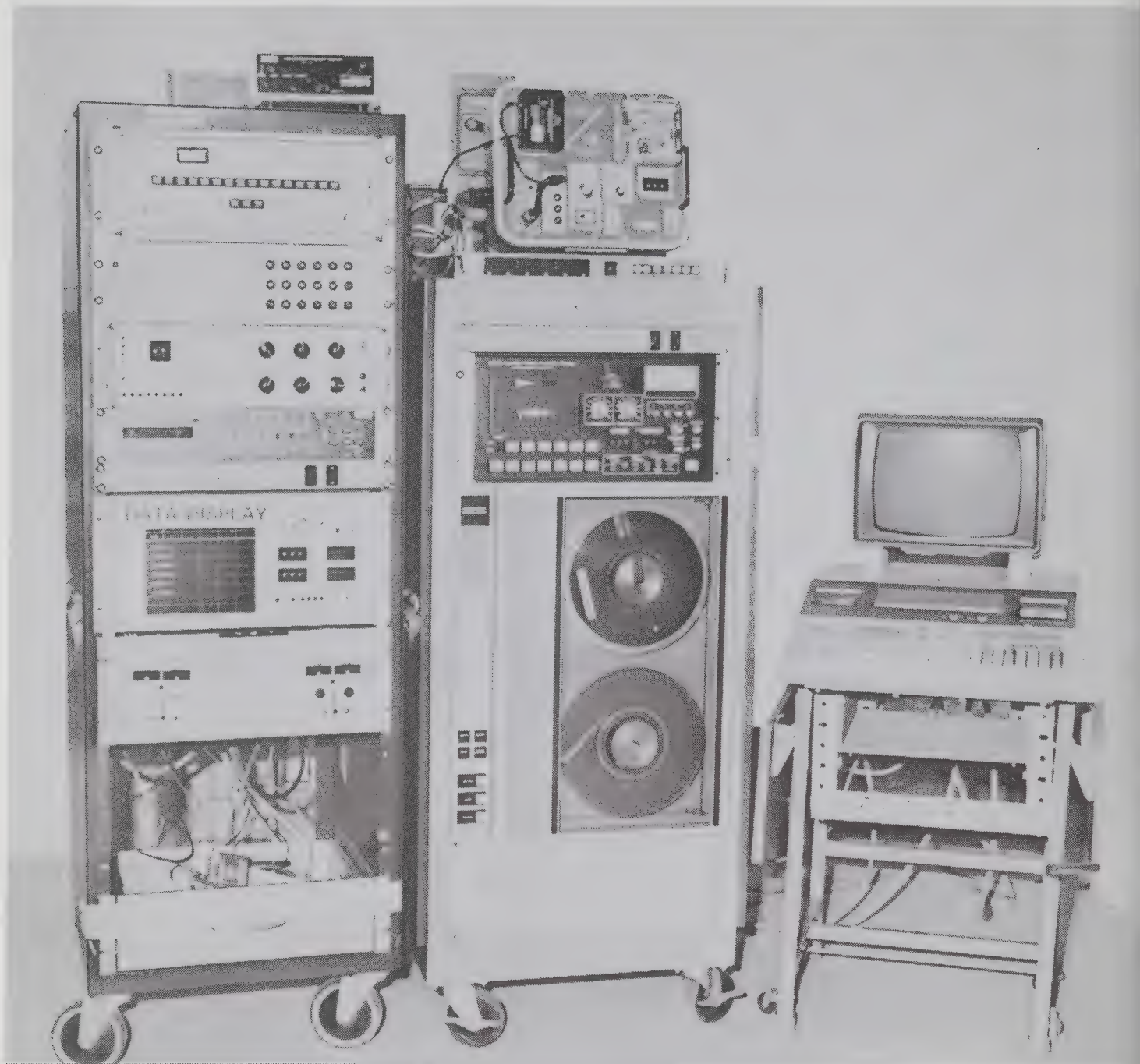


Figure 3 Logger for anchor station substudy

#### Moveable Current and Temperature Measuring System (MCATS)

MCATS is a current and temperature measurement system. The system is specially designed to measure the characteristics of processes near lake bottoms over periods of up to ten days. It consists of an array of three two-axis water current sensors and eight thermistors cabled to a digital data logger and system battery, all mounted or attached to a transportable frame (Figure 4). Each sensor is sampled every 16 seconds by the data logger.

During three successful missions in Lake Erie (1979) and a follow-up engineering endurance test, the system worked well and provided valuable and reliable data.

#### Portable Electrobathythermographs

To satisfy the increasing demand for portable temperature profiling systems for lake studies, two new models have been assembled. They incorporate an X-Y recorder, calibration circuits and a sensor power supply, all in a weatherproof enclosure. The

sonde is made up of standard self-contained, pressure and temperature transducers which are placed in a protective cage suspended by an electromechanical cable up to 100 metres long. The system is designed to be used from small boats and is for hand-over-hand operation. A temperature versus depth trace is produced on paper automatically as the sonde is lowered. These improved instruments will replace the standard electrobathythermograph system in the present portable units.

#### Programmable Timer and Controller for Chemical Analyzer

Repetitive tasks involved in controlling a fraction collector can be minimized by using a programmable timer. A commercially-available timer incorporating a microcomputer, originally intended for greenhouse control, was modified. External start and stop logic was added with two integrated circuits and connected to the control pins of the microcomputer to produce a timer suitable for the fraction collector. It can be programmed for up to ten different on-and-off times or start-or-stop times, as well as being manually controllable for setup purposes.



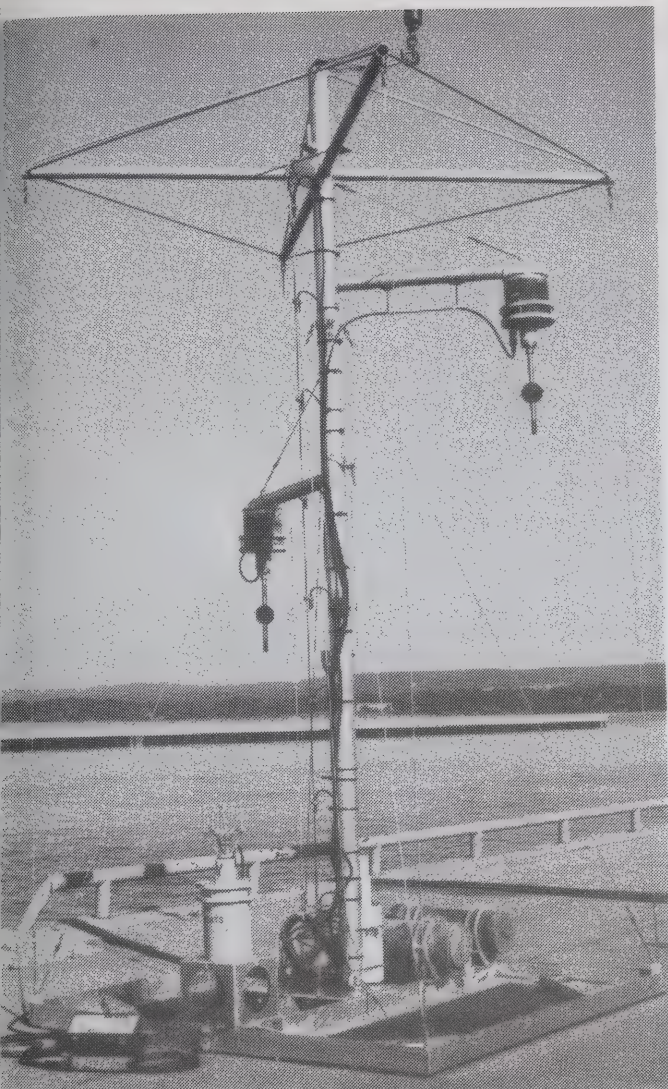


Figure 4 Moveable current and temperature measuring system (MCATS)

#### Sedimentation Trap Improvements

A sedimentation trap to study the settling of particulate matter in open-lake situations was developed, based upon a series of open-topped tubes suspended at intervals from a vertical mooring line. Previous models were deficient in that settled particles could be lost from the collector if the sampler were exposed to variable or strong currents. This tendency was minimized by using collecting tubes of large length-to-diameter ratio as demonstrated by Dr. L. Lau, Hydraulics Division.

The traps were also modified to facilitate their handling in the field and the retrieval of the samples. The lower portion of the tube consists of a replaceable plastic cup which on removal can be used for processing and shipping of the sample. The method of mounting the tubes on the vertical cable was also improved.

#### Slocum Organic Contaminants Sampler (Modified)

Organic contaminants occur in natural waters at such low levels that it is necessary to process large volumes of water to obtain sufficient material for chemical characterization. In doing so it is essential to avoid introducing contaminants from the equipment used.

The sampler was designed using a standard stainless Millipore filter holder with 0.3 micron glass filter paper to separate suspended particulates from the sample water. Attached to the filter holder is a Teflon column containing five specially cleaned polyurethane foam plugs which adsorb the dissolved fractions of organic contaminants from the sample water.

The sampler can be used from a ship in either of two ways: it can be lowered through the water column to the desired depth, and then sample water can be drawn through it at a necessarily low rate; or, the water sample can be pumped at a fast rate into a stainless holding tank by a teflon-lined pump, and the water passed through the sampler at the low rate while the ship is proceeding to the next sampling station.

#### Surveillance Multiband Transmittance and Temperature Profiler

In 1979 NWRI authorized the development of a multiband transmittance and temperature profiler to replace eventually the hand-over-hand Martek transmittance profilers now used on surveillance cruises. The new system incorporates a sensor with the standard light filters previously used plus accommodation for four other selectable filters, which may be required for remote sensing experiments. Electronics were improved to increase the stability and the linearity of the sensor, and temperature and depth sensors were installed in the sonde as well. The sonde was installed in a cage, balanced, and provided with shock mounts. The system time constants were verified in a tow tank. Two sondes were constructed to compare the influence of the field of view on the data. The signals are recorded on rack-mounted, X-Y recorders. Figure 5 shows the major components of the system. The winch is described further elsewhere in this report.

#### Television Monitors on Fish Stress Channel

The original Fish Stress Channel was designed and developed to evaluate the responses of fish exposed to toxicants then stressed by simulated stream conditions.

As a further refinement to the system, television cameras have been mounted on tracks on both sides of the simulator to monitor and record the activities of the fish remotely. The cameras are driven by an electric motor and chain to traverse the full length of the simulators viewing windows. The elevation of the cameras is manually adjustable. The new equipment is mounted inside light-tight housings which can easily swing out of position when not in use.

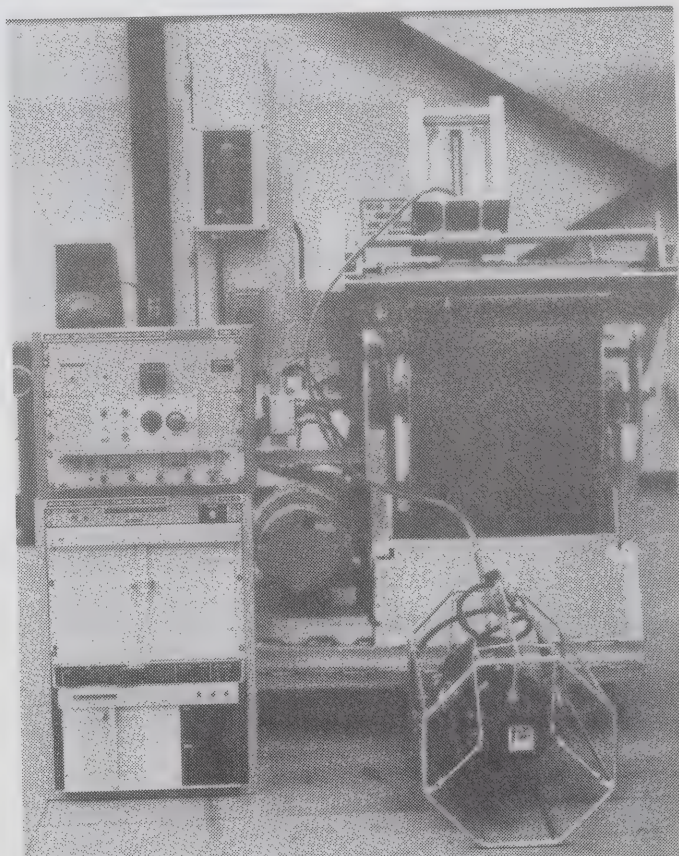


Figure 5 Surveillance multiband transmittance and temperature profiles



### Underwater Flash with Auto-Adjustment

To compensate for varying lighting conditions for underwater photography, a commercial-grade auto-flash unit with a remote sensor was repackaged in a suitable waterproof container. The remote sensor, which is placed near the camera, measures the returned light, then controls the duration of the flash to produce a reasonably constant exposure on the film. Laboratory and field tests proved the value of the unit in littoral zone research.

### Water Sampler Using Rosette System

Some advantages of having a Rosette Sampler System rather than traditional methods (clamp-on bottles and messenger) is that the sampling can be done at the desired locations because the temperature-depth profile is seen concurrently as the sampler descends to depth. The procedure is faster, the bottles are further away from ships' disturbance and several samples can be taken on one deployment.

This new system consists of a sonde which includes water sampling bottles plus temperature and pressure (depth) sensors, winch with a controller for depth sampling, and signal calibration and a visual display including digital signal readouts and an X-recorder. The system uses commercial products as well as custom controls and special devices.

### Winch for Moderate Sampling and Profiling Operations

As the surveillance operations are streamlined, so must be the equipment used for the task. The trend is to accomplish as much as possible on each cast. This means that the sondes must weigh more as they are required to perform more functions. A new generation of winch was designed, prototyped and tested. The winch (Figure 6) can perform a multiple of tasks such as handle sample which are pumped up through the electromechanical cable. The winch uses an electric drive and has all the safety devices required to protect the operators and the equipment.

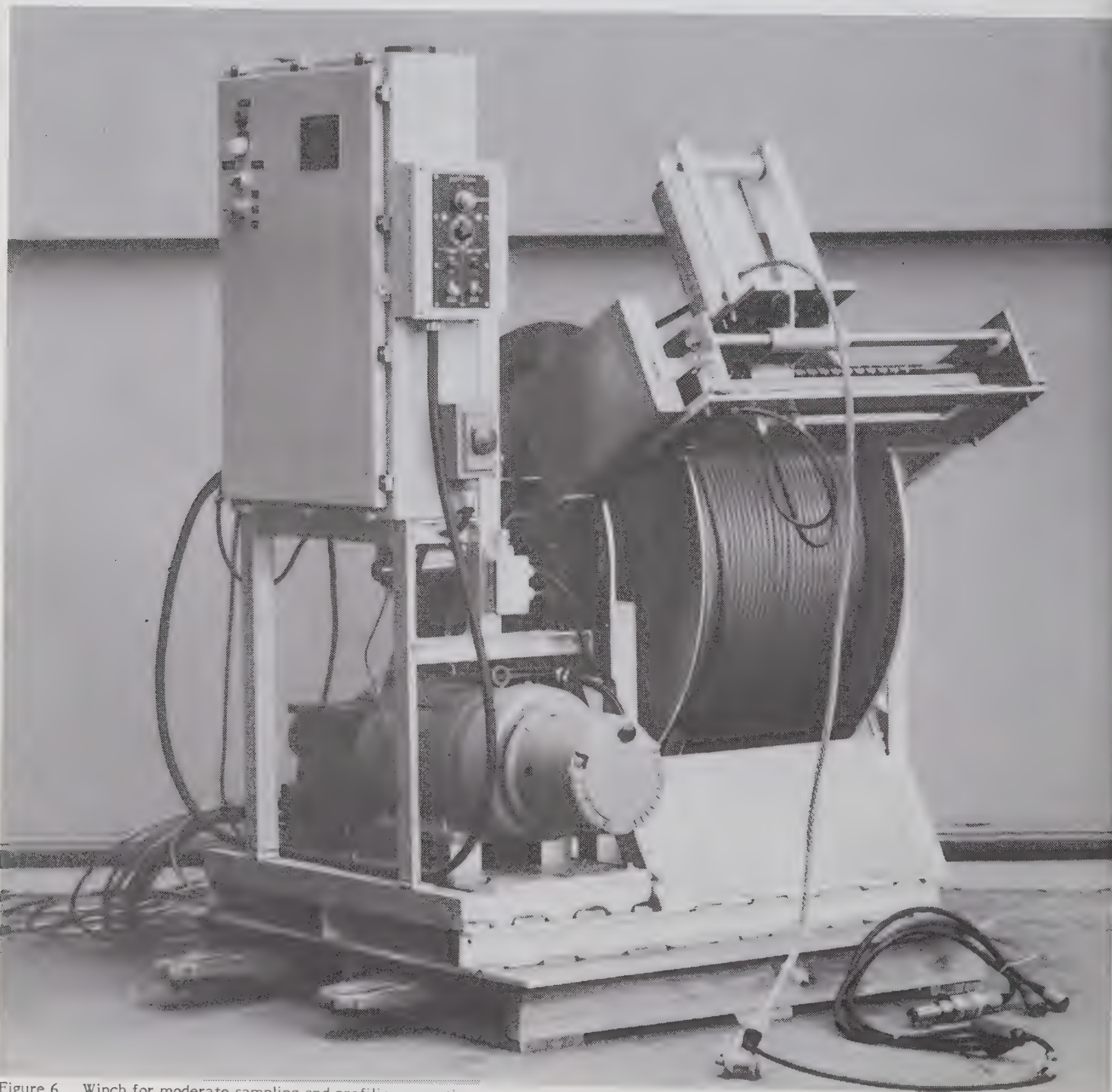


Figure 6 Winch for moderate sampling and profiling operations

Two installations were coordinated or assisted by the Division this year. The most significant was the main computer facility. Other installations are described in the following section as well.

#### Cyber 171

At 4:30 p.m., May 18, 1979, the Control Data (CDC) 3170 computer system at CCIW was shut down. This system, in three different configurations, had been in use since March, 1972. During that time 301,666 jobs were run, utilizing 14,338 hours of central processor time and requiring 172,412 magnetic tape mounts.

The CDC 3170 hardware was removed from the computer room on May 22 and installation of the CDC Cyber 171 hardware began on May 23. During the period May 22-27, extensive electrical renovations were made to the computer room power distribution system. Setup and connection of the Cyber 171 components were performed in parallel with the electrical work so that on May 25 power was applied to the Cyber 171 mainframe and hardware checkout began.

By Monday May 28, hardware checkout was essentially complete and system software installations commenced. The operating system, while not completely installed, had sufficient modules present by June 4 to begin production. The system was made available to the CCIW user community at 1:15 p.m., June 4, 1979.

The CCIW computer user community quickly adapted to the Cyber 171 system and its greatly improved capabilities. During the period June 1979 to March 1980, 41,917 batch jobs and 31,355 interactive sessions were run, utilizing 1,071 hours of central processor time and 22,313 magnetic tape mounts.

#### Raman Spectrometer Alignment

A Laser Raman Spectrometer manufactured by Jarell-Ash was transferred to NWRI. It was previously used for glaciology in the Inland Waters Directorate, Ottawa. When it arrived it was found that the double monochromator was severely out of alignment. Using standard alignment techniques, the monochromator was adjusted to give essentially the theoretical maximum resolution. This was checked by scanning across a spectral line of mercury hollow cathode lamp. The system as a whole was further checked by comparing the Raman spectrum of carbon tetrachloride to textbook values. The isotope shift was clearly evident. This alignment was done in cooperation with Dr. B. Oliver.

### CALIBRATION AND TEST FACILITIES' IMPROVEMENTS

While the state-of-the-art of instrumentation progresses in CCIW, the test procedures and facilities must stay ahead. Four significant improvements were made in 1979-80. They are the Pressure Test Facility, the Semiautomatic Water Velocity Sensor Calibration Systems, the Vibration Test Machine and the Reciprocating Test Unit.

#### Pressure Test Facility

A new pressure test facility has been designed, built and installed under contract to test submersible equipment at pressures up to the maximum found in the Great Lakes. The previous facility was too small and awkward to be useful for testing our equipment.

The facility is operated using water as the pressure medium while pressure is applied by an air-operated pump. All controls for filling, pressurizing, bleeding and emptying the tank are located on a control panel outside the room for safety reasons. The lid is O-ring sealed and is clamped to the body by means of two semicircular shoes which are moved by linked threaded bolts and are driven by a single operating handle. The lid is raised by a hand-operated winch and helpersprings. The lid-locking system is mechanically interlocked so that the vessel cannot be opened until all internal pressure is released.

#### Semiautomatic Water Velocity Sensor Calibration System

Calibration of novel current meters or sensors, employed in sophisticated, environmental measurement systems, requires special mechanical, electronic and software facilities to complement the CCIW tow tank facility. For example, some sensors have to be tested in three dimensions. A few mechanical fixtures have been designed and built to attach sensors and systems to the tow carriage. They provide safe, convenient mountings which permit manual rotation through 360° about the vertical axis, and some offer the equivalent 360° about the horizontal axis in 15° keyed steps. A motorized rotator with electrical slip rings gives a continuous changing flow direction for two axes sensors.

Electronic data acquisition, logging and display systems have been assembled from laboratory instruments, special interfaces and programmable scientific calculators. They automatically collect data from the sensors under tests, and other inputs such as the tow carriage displacement reference signal. The data are reduced, printed and plotted in real time, to provide the operator with a clear display of the test and calibration results, thereby reducing errors or omissions during intensive and exhaustive calibrations.

#### Vibration Test Machine

There are three main purposes for vibration-testing limnological equipment: mechanical endurance testing, measuring an instrument's responses to vibration, and troubleshooting intermittent instruments such as ones with loose contacts.

A vibration machine with modest specifications was purchased and made part of our environmental test facilities. Its main features are: a horizontal table, a variable-speed motor drive, adjustable eccentric weights, an air suspension system and capabilities of 3.2 gravities for a 90 kg load. This unit was selected to be large enough to hold most of our underwater instrumentation packages. The frequency and acceleration range reflect military standards for testing equipment for shipboard use.

#### Reciprocating Test Unit

An adaptable test unit has been set up for driving and testing electromechanical equipment and instruments. A typical example of application was on a commercially-built hand winch which was tested for Water Survey of Canada for correct operation and wear-out characteristics. Also the reciprocating test unit was used for calibrating a wave-rider buoy by subjecting it to a vertical simple harmonic motion and observing the signals from the buoy.

The reciprocating unit comprises a silicon-controlled rectifier electric drive, a worm gear reduction box and a chain reduction to the output shaft. The motor is capable of a 10:1 speed variation and is reversible by using limit switches. Cycles may be counted with a chart recorder or electric counter. Safety shutoff switches are provided. Output drives can be changed with a variety of crank throws and output speeds for each test as required. Everything is mounted on a rigid base.

### REGULAR SERVICES

In addition to special support assignments and consulting, there is support given continuously in various disciplines. These are the services which are given on an as required basis. They include operation of the main computer and ancillary computers, calibration and maintenance of instruments and equipment, production of illustrations and visual aids, provision of full machine shop services, operation of engineering stores - including tools, instruments and special parts - and the provision of projectionist services for CCIW's main auditorium. Approximately nine years of work per year goes into these services and the accumulated experience of the people doing the work total well over 200 years. These highly skilled and valuable people are becoming scarce in Canada.





## **TECHNICAL OPERATIONS DIVISION**



The Technical Operations Division is a service-oriented group of field specialists, whose mission is to provide logistical support and field party manpower to the NWRI off-site research programs. Specifically, the Division is responsible for both on-board and land-based data gathering, including sampling, sample preparation and, where appropriate, sample analyses.

This is a coast-to-coast responsibility, as the Division provides technical leadership and support to NWRI regions, other departments, agencies and universities.

#### SAMPLING OF LITTORAL DRIFT IN SUSPENSION AND LITTORAL DRIFT AND EROSION MODEL

These programs began in 1976. Van Wagner's Beach, Hamilton was chosen as the site for experimental measurements of littoral drift because of the accessibility, existing meteorological data collection system and the Beach Stability Program conducted there in 1972-73.

The SOLIDS sampling sled was designed and built at CCIW and occupied ten different stations, collecting samples at 1 cm, 10 cm and 30 cm above the bottom. Before every run, the sled was checked, then towed into the surf zone, employing a triariageway system. The samples are retrieved after the sled is turned to shore.

#### Complementary Measurements

To obtain wave height and direction, three wave staffs were attached to piles located approximately 6 m south, 3 m north and on line 7 at 243 m from the baseline. Wave height was also recorded at the WAVES tower. Also, a waverider was located 3 km from shore. In addition, three sets of two current meters were installed and data consisting of wind speed and direction, relative humidity, air temperature, currents and water temperatures from the WAVES tower were recorded 24 hours a day on magnetic tape. In May and September, bathymetric surveys were completed and charts of the area were drawn to measure sediment movement.

The analyzed data will indicate whether the system and techniques used for measuring sediment transport in the surf zone are adequate for the accuracy anticipated. The results of these and future tests will be applied to a mathematical predictor model of littoral drift.

#### PORT BURWELL MONITOR AND PORT BURWELL SURVEY

These programs were initiated in 1975 to study the problem of steep, unstable bluffs and high erosion rates of the Lake Erie shoreline near Port Burwell.

To monitor the cause and measure the rate and amount of erosion, each year a topographic survey was completed and a map of the area drawn; continuous punch tape records were kept of piezometer readings (groundwater elevation) and periodic readings of increase in borehole inclinations were recorded.

#### FIELD OBSERVATIONS OF BREAKING WAVES

Whitecaps provide a visual indication of the extent of wave energy loss and momentum transfer. Since whitecapping is a highly intermittent phenomenon, a photographic record was needed.

A 16 mm movie camera was installed in the housing on the north side of the CCIW research tower and posed at a predetermined angle to photograph the waves. One-hundred foot-rolls of film were changed once a week, alternating between colour and black and white. A total of nine rolls of film were shot and processed and delivered to Hydraulics Division for study.

#### PORT BURWELL NEARSHORE SAND DEPOSITS

The Port Burwell Study falls under the jurisdiction of Environmental Management Service National Program 32, Shore/Coastal Zone Management. The resources of the Shore Processes Section of Hydraulics Research Division and of Technical Operations Division were mobilized to provide data and an analysis of nearshore sand deposits in the vicinity of Port Burwell.

## ACID RAIN

Many of Canada's smaller lakes are already suffering ill effects from concentrations of airborne pollutants such as sulphur dioxide.

A five-year study has been launched by the federal government in the Algoma District near Sault Ste. Marie along the east shore of Lake Superior. Several government agencies are involved and a concentrated effort will be made at the Turkey Lakes Research Site within the District over the next few years. Much of the 1979 research was used in determining the location of the sampling site as many factors had to be considered. The GLBL group conducted a Headwater Lakes Study throughout the season on many of the proposed project lake systems. Scientific methods and procedures used throughout the program will be similar to those that have been used by the Provincial Government in their Acid Rain Study at Dorset, Ontario for the past few years.

Technical Operations Division supplied logistical field support for two major field programs being carried out in the Sault Ste. Marie area during 1979 by National Water Research Institute and Great Lakes Biolumnology Laboratory. This support was given in terms of manpower, vehicles and equipment that was shared between the two programs as workload dictated.

#### QUINTE/DORSET PROGRAM

This year's support to the Quinte/Dorset surveys was again managed under Project Number GLBL-020. Most of the time was spent on the acid rain part of the program at Dorset, Ontario. The study involved the weekly sampling of: zooplankton, temperature, larvae fish, minnow traps and Ekman grab for chironomids on Harp Lake and Plastic Lake.

#### CANADIAN WILDLIFE SERVICE

Technical Operations supported the CWS with their field requirements during the 1979 field season. These projects are part of the Wildlife Contaminants Surveillance and this, in turn, is part of the IJC. The support consisted of a full-time technician from April 9 - August 10, a vehicle and other assistance from the Technical Operations Shop and personnel. A short description of 1979 projects is listed below:

- to determine toxic chemical residue levels in Herring Gulls from colonies on the Great Lakes.
- to determine the reproductive success of several Herring Gull colonies throughout the Great Lakes.
- to collect 100 Herring Gull eggs from colonies in western Lake Erie to be used as a standard and check sample.
- to survey areas in Lake Huron and Georgian Bay for breeding sites of colonial nesting birds.
- to determine variation between the eggs of normal three-egg nests of Herring Gulls by collection of feathers from developing birds.
- to determine the contamination levels in sequentially laid Herring Gull eggs.
- to assess the feasibility of using feathers as an indication of heavy metal contamination.

The amount of work and number of projects was expanded from 1978 and required increased personnel, which consisted of two biologists from CWS, one technician from CWS and three contract personnel hired for various time periods. The boat requirements also increased and consisted of the 17-foot launch THUNDERBIRD, a 17-foot Boston Whaler, a 14-foot Starcraft aluminum boat and a 12-foot inflatable rubber boat. Each had its own trailer and motor which were supplied by Ocean and Aquatic Sciences. These boats travelled a total of 2471 miles on nearshore areas of the Great Lakes.



Lake Ontario

## Surveillance

The Open Lakes Surveillance Program was designed to provide a continuing report and long-term trend information on water quality and eutrophication parameters in the Great Lakes. During the 1979-80 field season, data collected from 94 stations on Lake Ontario will serve as input to the Canada-U.S. Agreement for the Water Quality Board Annual Report to the International Joint Commission (IJC).

Nine surveillance cruises were supported by Technical Operations Division on Lake Ontario. The cruises were conducted from the CSS LIMNOS, operated by Ocean and Aquatic Sciences. The ship was equipped with electronic bathythermographs, Rosette/-electronic bathythermograph system, radar and Loran C positioning systems and a variety of winches used for chemical, biological and water clarity sampling.

During the 1979-80 field season, there was one other major project conducted by the CSS LIMNOS on Lake Ontario. This project was to support the Winter Thermal Plume Survey at Ontario Hydro Pickering Generating Station.

Technical Operations Division supported this project by providing all hardware necessary for the moorings and the expertise for the installation of ten U-shaped current meter moorings and two CATTS SYSTEMS. The moorings are scheduled to be retrieved in early spring 1980.

Lake Erie

During the 1979/80 field season, 17 cruises were completed by the major research vessel on Lake Erie. These multidisciplinary cruises consisted of:

- 8 - Sediment Trap Moorings
- 3 - Lake Physics Studies
- 3 - Vertical Fluxes of Organic Carbon
- 2 - Moorings: Current Meters, Meteorological Buys, Fixed Temperature Profiles
- 1 - Lake Erie Benthic Survey

Two major mooring cruises were carried out in the 1979/80 field season: an installation and a retrieval cruise.

A total of 21 current meter moorings: six meteorological buoys and five fixed-temperature profile moorings were positioned in the eastern and central basins of Lake Erie. The purpose for the installation of this instrumentation was to undertake a detailed exploration of nearshore flow in the central basin of Lake Erie and a study of the vertical structure of currents and temperature in the mid-basin area. This project also was to provide physical data for NWRI chemical and biological studies and to complement a lake-wide circulation experiment being carried out in Lake Erie by U.S. scientists. This program was carried out in conjunction with the Lake Physics Study of Lake Erie and programs complemented each other.

All systems were monitored on a two-week cycle and Hymet recorders were renewed on an average of 31 days. MV LAC ERIE was utilized to service the meteorological systems and CSS ADVENT assisted as her schedule permitted.

## Lake Physics Study

Three Lake Physics Study Cruises were carried out on Lake Erie during the months of July, August and September. The purpose of these cruises was the same as that of the mooring cruises.

On each cruise, a waverider mooring, M-CATS and a cluster of drogues were deployed. The thermal structure was measured by an array of 12 thermistors and one pressure transducer. The Rosette water sampler was used to collect water samples from specific depths in the water column for chemical and biological analyses. Light transmission profiles were also collected during the anchor experiment.

## Vertical Fluxes of Organic Carbon

During the months of June, July and August, Vertical Fluxes of Organic Carbon Cruises were completed on Lake Erie. The purpose of these cruises was:

- (i) To estimate the flux of particulate organic carbon entering the hypolimnion from the epilimnion during the stratification season, using sediment traps.
- (ii) To describe the vertical movement of the different classes of particles traversing the thermocline.
- (iii) To describe the nature of particles occurring at different depths and relate these findings to other limnological processes affecting the particles.

This program formed a major part of the final year of a three-year study to elucidate and quantify the important processes controlling hypolimnetic oxygen uptake in Lake Erie.

## Sediment Trap Mooring Cruise

The Sediment Trap Mooring Cruises began on April 23rd and ran once every two or three weeks for a period of four days until the completion of the program on October 18th. The purposes of these cruises were:

- (i) To determine the algal growth, maintenance and decomposition rates in the epilimnion of Lake Erie, enabling a calculation for the net water column production of organic material to be made. These values are to be compared to sedimentation rates.
- (ii) To test the hypothesis that hypolimnetic oxygen depletion rate is a function of the sedimentation of labile organic particles.

In support of this project, a total of eight cruises were carried out on Lake Erie. Sediment traps were positioned at 15 locations in the eastern and central basins of the lake. In conjunction with this project, microbiology samples were collected. Also, on selected cruises, primary productivity moorings and triple benthos cores were included in the sampling program. On all cruises, samples were collected for spatial (horizontal and vertical) radiobioassay for estimates of phytoplankton and bacteria phosphate demand.

## Lake Erie Benthic Survey

This was the only cruise of this nature carried out aboard the CSS LIMNOS during the 79-80 field season. The purpose of this cruise was twofold: first, the Surficial Sediment and Benthic Fauna Survey of the Western Basin of Lake Erie which began October 1978 was completed; secondly, an Echo Sounding Survey was conducted from Nanticoke on the north shore of the lake to Erie (Presque Isle) on the south shore.

## CSS ADVENT

Lake Erie

The CSS ADVENT's input into the Lake Erie Physics Program consisted of two types of surveys:

- (i) Thermocline Contact Cruises, and
- (ii) Temperature Mapping Cruises.

## Thermocline Contact Cruises

The purpose of these cruises was to map the zone of contact of the central basin hypolimnion with the shoreline on the north side of the basin. Earlier work had suggested that this shoreline was an area of upwelling and that this upwelling might be instrumental in forming a mass of mixed water which would then move offshore at thermocline depths. The observations collected during the thermocline mapping cruises tended to confirm this hypothesis but further analysis is required before the importance of the process can be determined.

## Temperature Mapping Cruises

The temperature mapping cruises were used to collect quasi-synoptic temperature profile data in the vicinity of the central basin current meter array. This data was used to help establish the spatial variability of the thermal structure within the array and thereby help assess how well this thermal structure was mapped by the combination of fixed temperature profiler and current meter data. As a secondary purpose, the information provided a check on the performance of the moored instruments.

## Frequency of Surveys

The Thermocline Contact Cruise was run on a regular basis with a twice-weekly coverage being maintained. The Temperature Mapping Cruise was run once a week.

## SPECIAL PROJECTS UNIT

The Unit supported an increasing variety of projects for both NWRI and outside agencies, and support continued to regional offices.

More common support in the form of logistics, instrument maintenance and data quality control was provided for the following systems:

Meteorological	Radiation
Temperature	Rain Gauges
Transmissiometer	Geological Samplers

## Meteorological Systems

Eleven meteorological buoy or tower systems were maintained, yielding 70 months of data. One of the major installations was at Jack Lake, Ontario where fixed temperature profilers and radiation systems -- solar, reflected and underwater -- were also maintained. The Jack Lake Research Project was provided with a 50-foot lab trailer, a utility shed, hydro, sewer and water facilities and three docks.

## Radiation Systems

Fifteen radiation systems were maintained, yielding 130 months of data. The implementation of the Campbell Scientific Integrator has reduced the data processing time by 65 percent.

## Geological Sampling Gear

There has been an increase in the use of sediment sampling and coring equipment maintained by the Unit, which was frequently called upon to demonstrate equipment and to participate in field exercises. Some of the projects included 18-metre piston cores in Lake Huron for Lakehead University, lightweight corer samples from ten lakes in the Sudbury area for heavy metals and more than the usual number of grab samples from Hamilton Harbour and Lake Ontario.

## Solar Eclipse

The last total solar eclipse on the continent this century was documented on charts and film at Arborg, Manitoba on February 19. The moon, in between the sun and earth, cast its shadow on the earth; during the three minutes of totality, the temperature dropped about ten degrees C.

## DIVE UNIT SUMMARY

The requirements for Dive Unit support increased by 30 percent in 1979 from 1978. The increase from 17 support projects to 24 necessitated a considerable amount of extra dive time for the individual Dive Unit members.

There was a trend in 1979 to use divers for scientific survey purposes rather than, or as well as, the nut-and-bolt diving of other years.

Projects supported within NWRI included seven Hydraulics Division projects, four Applied Research Division, four Process Research Division and three Engineering Services Section projects.

Outside agencies supported were Ocean and Aquatic Sciences, Burlington (ship inspections and field equipment installation), Ministry of the Environment, Toronto (equipment installation and maintenance), University of Waterloo (instrument installation), University of Guelph (field survey) and McMaster University (instrument installation).

The geographical areas of support included Lakes Ontario and Erie, Buckhorn Lake, Jack Lake and Lake Manitoba as well as Hamilton Harbour and the St. Lawrence River.

## RIGGING UNIT

A rigging foreman and staff of two riggers maintained and supported all equipment used by Technical Operations Division. During the winter months, all buoys, sampling equipment, winches, generators and a variety of materials were overhauled and made ready for the survey season. Support was also given to many senior marine technologists carrying out field support activities. In the summer constant support was given to the ship- and shore-based surveys which involved the delivery of equipment to ships which operate on the lower lakes and the towing of out-size and normal trailers to various locations.

The Rigging Unit has increased its responsibility areas to include NWRI Vehicle Maintenance and the Warehouse. The purchase of a new forklift for the warehouse and the reorganization of Field Stores have been major additions to the Unit.





## **STAFF SERVICES DIVISION**



Staff Services is the lead agency for the provision of administration, financial, materiel management, records management and property management to all Environmental Management service elements located at the Canada Centre for Inland Waters. In addition, common services were provided to Fisheries and Oceans which includes Ocean and Aquatic Sciences Central Region, Great Lakes Biolimnology Laboratories and Canadian Hydrographic Service, Environmental Protection Service, Department of Supply and Services and Personnel Administration (Ontario Region). Expertise is also provided to supporting committees such as facilities, safety, security, fire prevention and energy conservation.

#### Financial Section

During the past fiscal year, financial accounting facilities were provided to all EMS units at the Centre as well as the Great Lakes Water Quality Agreement for the Regional Director General (Ontario Region). It is estimated that in excess of 20,000 invoices and travel claims were processed during the fiscal year.

#### Building and Property Services Section

This Section provides support for the physical operation and maintenance of facilities including repairs to intrinsic building equipment. It also provides technical assistance and advice concerning alterations, modifications or equipment installation to all CCIW facilities to satisfy in-house occupant requirements.

In addition, this Section is responsible for ground, roadway and parking lot maintenance, telecommunications and service Contracts coordination, safety, fire or emergencies, security and safety/security programs for the Centre. All contractual services are carried out in accordance with the Facilities Planning Systems and Procedures Manual.

The energy conservation program continues to be stressed. Gas and hydro consumption has been reduced by 50 percent and 18 percent respectively from the 1972 level. The Chief Operating Engineer, Mr. D. J. Smith was the recipient of a merit award for work in the field of energy conservation.

#### Telecommunications

The Building and Property Services Section is responsible for a 550 line PBX servicing over 500 telephones, data and other communications systems throughout the Centre. This Section advises on new or changing equipment, updated systems and coordinates movement of equipment.

#### Fire Protection, Safety and Security

There were no major incidents during 1979-80. Safety committees involving employees in CCIW pay considerable attention to potential problems and immediate action is taken to correct problems before incidents arise. First aid programs and driver safety programs are ongoing. Heat and smoke detection systems have been enlarged to cover more areas in the Centre and alarm systems have been upgraded in several areas. In addition, panic bars have been installed on all stairwell doors to prevent spread of fire or smoke.

#### Materiel Management

During the 1979-80 fiscal year a reorganization of this Section has taken place. As the majority of inventory items in the warehouse and field stores is in support of field operations, the control of this area has been transferred to the Technical Operations Division. Personal issues of protective clothing and loan clothing is made to all units located at the Centre.

A complete equipment-in-use inventory is maintained to record the Centre's assets and updated daily as equipment is received, transferred, disposed to CADC or written-off.

#### Central Registry

Staff Services provides mail services to all in-house occupants as well as registry facilities for NWRI and Inland Waters Directorate. Telex, telecopier and photocopying services are provided for the Centre.





## REGIONAL REPORTS





## PACIFIC AND YUKON REGION

The regional branch is organized to do interdisciplinary research which has application in regional programs of the Inland Waters Directorate. To accomplish this task, there are staff and facilities in the branch for studies in physics, geology, chemistry and biology.

The branch was involved with two major programs over the 1979-1980 period: 1) a study of the effects of upstream poundments on the limnology of Kootenay Lake; and 2) a study on the degradation and dispersal of the herbicide 2,4-D, which is being used to control the spread of Eurasian Water Milfoil in lakes of the Kootenay Valley.

### Kootenay Lake Limnology

The major effort of the branch was applied to the interpretation of field data collected in 1976, 1977 and 1978. The report summarizing this work will be released in the summer of 1980.

Dams have been built on each of the two major rivers supplying water to Kootenay Lake. The dams now control 55 percent of the inflow and have caused alterations to the annual hydrology and to the loading of nutrients and suspended sediments. Although the changed hydrology has had little effect on the seasonal development and short-term nature of the lake's temperature structure, it has resulted in a halving of the nutrient supply (phosphate) to the phytoplankton during the summer growing season, and a reduction in surface water turbidity during late spring.

The heavy metal geochemistry of the sediments reflected high levels of mineralization in the drainage basin and the intensity and timing of mining activity. Near the old mining centres (Ainsworth and Riondel the concentrations of some heavy metals (Pb, Zn, As) in the sediments is as high as, or higher than, any reported in the open literature.

There was evidence that the lake did not mix completely during winter, despite the fact that it is ice free. The degree of mixing did occur depended on the temperature and salinity of the largest input river (Kootenay River). As a result the residence time of pollutants and estimates of rates of reequilibrium of nutrients had to be established using models of (physical) circulation that were more complex than those in general use.

Biological investigations showed that populations of organisms smaller than 5 µm were a very important part of the plankton community. For example, at many times of the year their biomass made up almost 50 percent of the total whilst their phosphorus uptake and photosynthesis were 80 percent and 50 percent respectively. A direct and important change to the ecology of Kootenay Lake has been the extreme proliferation of the indigenous mysid shrimp, *Mysis relicta*. After its introduction to the lake in 1949-50 as a supplementary food source for game fish, it reached population densities that are higher than any recorded elsewhere. The effect this has on the lake's ecology is not yet fully known, but it is now well established that the export of mysids from the main lake into the West Arm (outlet river) is the main flood supply for a major sport fishery in the West Arm.

### Degradation and Dispersion of 2,4-D

This project was begun in the summer of 1979. The sampling coincided with applications of the herbicide by the British Columbia Ministry of the Environment in Wood and Kalamalka lakes. To properly interpret the results of these surveys, laboratory tests of hydrolysis rates under different temperature and pH conditions were carried out. Improvements in the analytical methods have been made in cooperation with the regional Water Quality Branch laboratory. These refinements were especially crucial to measuring the levels of 2,4-dichlorophenol residues, one of the degradation products of 2,4-D.

### Methods Development and Miscellaneous

A new technique, that of filter fractionating populations, has been developed for the measurement of microbial biomass and nutrient dynamics. A procedure for estimating areal phytoplankton

productivities using an incubator method was established. Laboratory and *in-situ* measurements were combined in a computer program developed by the branch.

The oceanographic method of using two- and three-dimensional property-property diagrams was extended to understand the internal transfers of mass and energy in a lake influenced by large rivers. The data was manipulated in volumetric space with a computer program developed in the branch. A new mass-curve budget is presently being formulated for general application to riverine lakes.

A semiroutine method for measuring the phosphorus forms in sediments and suspended sediments was developed by modifying techniques used by the late J.D.H. Williams of NWRI, Burlington. The modification allows the determination of three phosphorus fractions in very small samples (< 100 mg).

The study of interannual temperature structure variations in Kootenay Lake has continued. The data provided so far has been useful in linking the time of a fish kill in 1979 to the occurrence of a large internal wave.

## WESTERN AND NORTHERN REGION

### Introduction

The National Water Research Institute, Inland Waters Directorate, Environmental Management Service, Western and Northern Region (NWRI-WNR) is located at the Freshwater Institute, 501 University Crescent, Winnipeg, on the University of Manitoba campus.

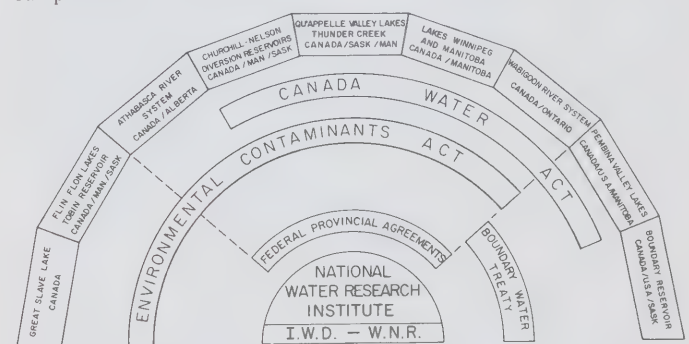


Diagram 1 Study sites and Federal mandates: National Water Research Institute - WNR

NWRI-WNR conducts applied research at specific sites where regional water management problems need to be or can be resolved. The research conclusions support federal water management programs conducted under various mandates such as the Canada Water Act, the Environmental Contaminants Act, the Toxic Substances Act, the Boundary Waters Act, the Department of Environment Act, EARP, the Arctic Water Pollution Prevention Act, and various Federal-Provincial Agreements. Lakes and reservoirs studied (outer ring of Diagram 1) are on interprovincial or international rivers, federal lands, or are sites where there is a clear and often multiple federal interest (inner arcs of Diagram 1). The immediate objective is to become able to predict the response of specific regional freshwater systems to the impact or removal of various environmental stresses. The stresses focused on are:

- (i) Nutrient rich effluents of urban or agricultural origin.
- (ii) Toxic substances from industrial (mainly mining), agricultural or urban sources (including acid precipitation).
- (iii) Reservoir construction and operation related to thermal or hydro electric power generation (including river diversions).

Two other stresses affect regional freshwater systems and they may be added to the above list in future.

- (iv) Drought, its frequency and intensity.
- (v) Radioactivity resulting from uranium extraction and nuclear power generation.

A continuing function is the development of expertise in regionally specific water management problems and the controlling processes in freshwater systems in WNR. For example, the semiarid character of the prairies, the unusual hydrograph (ratio of spring runoff to total discharge is among highest in the world) of prairie streams and other factors result in a unique Canadian freshwater system. Transfer of conclusions based on sites elsewhere in Canada to regional sites is tenuous. Transfer of conclusions between similar regional sites is more valid but in many cases the fine detail of freshwater responses to various stresses remains site-specific. As specific sites are studied, specific recommendations can be made on environmental effects of water resource development alternatives. As more regional sites are examined, a broader understanding of freshwater systems in WNR evolves, so that predictions of inter-jurisdictional effects of water resource management decisions become more valid.

## Aquatic Ecology

The shallow lakes of the main interprovincial and international streams of the prairie region are naturally rich in nutrients and highly productive. Algal blooms during summer months are a nuisance phenomenon thought to be exacerbated by excessive quantities of nutrients introduced into Prairie rivers and lakes from urban point sources or diffuse agricultural sources. In the semiarid prairies, larger lakes are rare and therefore a prime recreational and tourist attraction. Many larger lakes are ringed by cottage developments. Such lakes include those of the interprovincial Qu'Appelle River of southern Saskatchewan, the international Pembina River of southwestern Manitoba, and Lakes Winnipeg and Manitoba. At all sites, nutrient enrichment occurs from agricultural activity. In addition the Qu'Appelle lakes downstream from Regina, and Lake Winnipeg downstream from Winnipeg, receive large inputs of phosphorus and nitrogen from city sewage effluents. The Federal-Provincial Qu'Appelle Valley Implementation Agreement allocated several million dollars for construction of a tertiary water treatment plant to remove phosphorus from Regina's effluents and for other facilities and procedures to reduce nutrient loading to the lakes from both urban and agricultural sources. These decisions had to be made on a very limited data base because of the very low level of investigation of nutrient-productivity relationships in prairie lakes in general. A future decision will be to determine the validity of tertiary removal of phosphorus from Winnipeg sewage. Because of the historical evidence for high natural productivity in these prairie lakes, the degree of productivity reduction or other effects of nutrient removal or enrichment are not clearly understood. Thus large Federal and Provincial expenditures aimed at productivity reductions are based on a relatively scant research base.

The purposes of the ongoing research at the sites in southern Saskatchewan and Manitoba are:

- (i) To refine our knowledge of nutrient-productivity relationships in shallow prairie lakes.
- (ii) To refine predictions as to the effects of multidollar nutrient removal schemes.
- (iii) To devise on-site rehabilitation or restoration methods for naturally highly productive (hypertrophic) lakes.

Any scheme put into effect on such river-lake systems as a result of research conclusions may have downstream effects in other provinces or internationally and thus requires a federal involvement.

## Nutrient Loading Models:

On the Qu'Appelle River (Figure 1), the magnitude of the spring runoff can dramatically alter the annual phosphorus loadings to and predicted trophic state of small lakes in the semiarid prairies of Canada (Allan and Kenney, 1977). The four Fishing Lakes of southern Saskatchewan have highest loadings (up to 25 g/m<sup>2</sup>) in medium and high runoff years. In low runoff years, loadings fall to 3.3 g/m<sup>2</sup>. Based on recent models, high spring runoff years are the least trophic. Artificial spring flushing could augment P loading reduction as a means of further lowering trophic level. Spring runoff has another important function of flushing P regenerated under river ice. In drought years, late winter TP concentrations of up to 600 mg/m<sup>3</sup> extend into the spring while, in flood years, concentrations are drastically reduced. Average summer chlorophyll-

a concentrations are very high. Predicting chlorophyll-a from loading appears to be accurate. However, models predicting chlorophyll-a from lake P appear to overestimate the true concentrations and if correct could be related to very low TN/TP ratios (low as 2) found in the Fishing Lakes (Allan and Roy, 1980).

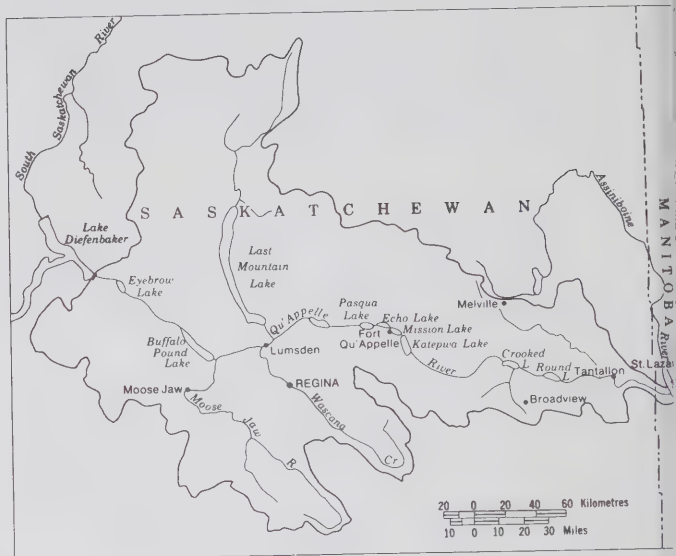


Figure 1 Qu'Appelle River basin

## Nutrient Loading - Productivity Models:

Studies of productivity and N and P chemistry of the lakes by Allan and Kenney (1978) and by Cross (1978) conclude that the Fishing Lakes are N-limited rather than P-limited. Allan and Kenney arrived at this conclusion from productivity-lake TN/TP ratios. Mean summer algae biomass should have been higher. Examples in the literature of hypertrophic lakes with less than expected mean summer chlorophyll-a are those with low total nitrogen to total phosphorus ratios. Such low ratios presently exist in the Qu'Appelle Lakes because of the extremely high phosphorus concentrations of 500 and greater µg/l TP. In 1977-78, TP occasionally exceeded TN (Allan and Roy, 1980). Phosphorus removal is the accepted aim of the water quality improvement schemes. This should cause TN/TP ratios to rise with unknown effects on mean summer algae biomass. A contracted analysis of inflow and outflow P and N chemistry of the Qu'Appelle Lakes (Cross, 1978) also concluded that Fishing Lakes are presently N-limited. The Fishing Lakes are the first four lakes downstream from Regina. Further downstream, Crooked and Round Lakes were P-limited. The question arises as to how much P must be removed from the Fishing Lakes to return them to P limitation and if this occurs will it correspond to a reduction in summer biomass.

Because large reductions in phosphorus loading are required to cause small decreases in mean summer phytoplankton biomass, inaccuracies exist in 1) predicting lake phosphorus concentrations from phosphorus loading models and mean and maximum chlorophyll-a from lake phosphorus concentrations and 2) representative sampling to estimate the phosphorus loading and true mean maximum chlorophyll-a. Remedial measures to reduce external phosphorus loads - and hence lower in-lake phosphorus concentrations from some 600 mg/m<sup>3</sup> to much lower values of some 100 mg/m<sup>3</sup> will result in the reduction of long-term (several year average) mean and, more significantly, maximum - open-water summer chlorophyll-a concentrations. However, despite the application of these remedial measures, perturbations in phytoplankton biomass will remain such that, on any particular day during the open-water period, short-term algal blooms or scums will still be sufficiently intense that long-term improvements will not be clear evident to the casual recreational user of the lake. The possible relationship between very high phosphorus concentrations and phytoplankton biomass, as represented by chlorophyll-a, was derived from a series of limnocorral phosphorus addition experiments conducted in Rock Lake, Manitoba during 1978 and 1979 (Figure 1) (Allan, 1980).

## Role of Sediment Phosphorus in Hypertrophic Lakes and Relations to Historical Trophic State:

Extreme spring phosphorus concentrations in the Fishing Lakes is thought to be related to internal loading from sediment



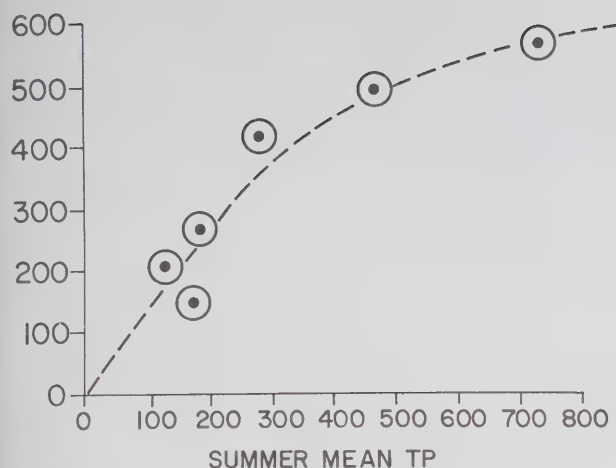


Figure 2 Extreme total phosphorus concentrations vs. maximum chlorophyll-a.

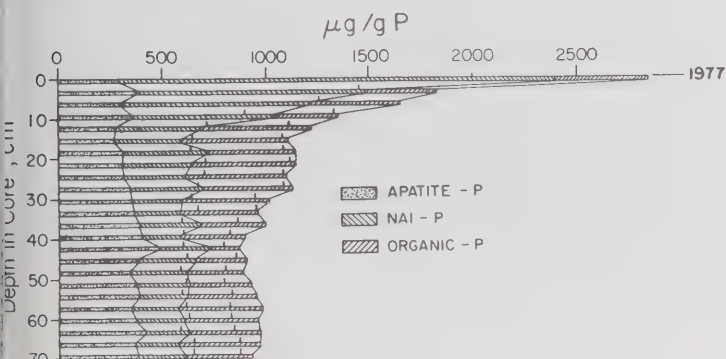


Figure 3 Phosphorus form distribution down a sediment core from Mission Lake

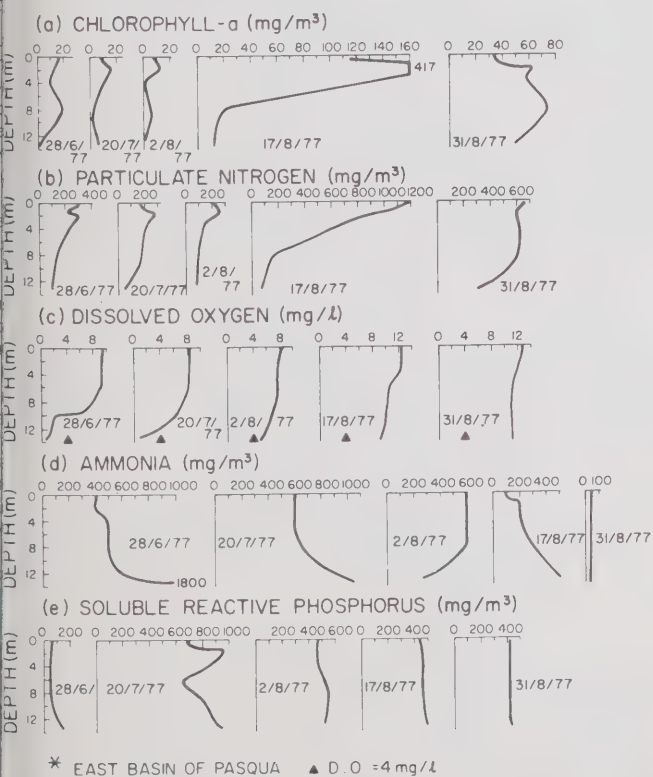


Figure 4 Relationship between D.O., SRP and  $\text{NH}_4\text{-N}$  in Pasqua Lake.

bioavailable phosphorus (Allan and Williams, 1978) or from sediments and decomposing seston under ice (Warwick, 1979) or perhaps from groundwater injection (Laksham, 1979). Most likely all three processes are involved to varying degrees (Allan and Roy, 1980). Rough calculations of under-ice, winter-lake phosphorus levels indicate a possible release rate of some 8 to 9  $\text{mg/m}^2/\text{day}$ . Sediment core phosphorus analyses show surface enrichment of bioavailable-P (NAI-P) especially in Mission Lake (Figure 3) (Allan et al, 1980). High phosphorus concentrations are carried over into the late summer months (Figure 4) in the form of a chemocline. Late summer mixing can produce maximum chlorophyll-a levels.

In terms of historical (pre-1880 settlement of the prairies by farming communities), nonapatite (NAI-P plus O-P) phosphorus concentrations in sediment cores (such as in Figure 3) indicate that most prairie water bodies were eutrophic prior to settlement (Allan et al, 1980). Cores from five mainstem lakes and two prairie potholes were analyzed. Nonapatite phosphorus concentration increases towards the sediment surface are, however, taken to indicate increases in phytoplankton biomass since settlement. These surface sediment NAI-P increases are the result of urban and agricultural effluents probably modified by surface pooling of phosphorus under chemical, physical and biological controls, further modified by possible groundwater injection.

A necessary part of the core study was measurement of sedimentation rates by radio-chemical techniques. The high sedimentation rates found (Durham et al, 1980) indicate rapid filling of the Fishing Lakes relative to lakes in other physiographic environments such as the Canadian Shield.

#### Hypertrophic Lake Restoration Experiments in Large Diameter Limnocorrals Installed in Rock Lake, Manitoba:

During 1978 and again in 1979, five large diameter limnocorrals were installed in Rock Lake, Manitoba. The corrals were subjected to a variety of treatments focusing on raising phosphorus concentrations to extreme levels, raising nitrogen levels to extreme levels and manipulating TN/TP ratios. Tests were also made of the effects of such lake restoration treatments as alum and bentonite additions. Besides its similarity to the Qu'Appelle Lakes, Rock Lake was selected because of provincial concerns and partly for logistical reasons (approximately three visits per week from Winnipeg are required). A laboratory trailer provided by the Province of Manitoba was established at the site. The lake and the Pembina River inflow were also monitored. The P, N and alum treatments were made weekly. The bentonite treatment was at the start of the season. Water chemistry, chlorophyll-a and algae speciation were monitored weekly. The experiments ran from July 1st to the middle of September, 1978 and 1979. Results are now being compiled for future interpretation.

#### Palaeolimnology (Historical Eutrophication and Contamination) of the Fishing Lakes:

Benthic studies and palaeolimnological studies are two approaches to providing an insight into the historical deterioration, increase in productivity or eutrophication of the Qu'Appelle Lakes. Lake water chemical and algal analyses provide situation estimates on a relatively short time scale. Benthic studies introduce time scales in the order of years while palaeolimnological studies extend the time scale to tens and hundreds of years. Both studies concentrate on the family of dipterous insects, the Chironomidae, whose life cycles and physiological responses to the aquatic environment make them particularly useful in analyzing the progress and extent of eutrophication processes (Warwick, 1978). Benthic studies on live Chironomidae populations are particularly useful in studying the extent of eutrophication in aquatic systems and thus in indexing the trophic state of a particular body of water, i.e. each of the individual Qu'Appelle Lakes. The family is equally useful in the palaeoecological characterization of the progress of the eutrophication since the same classification system can be applied to the fossil remnants of the family. Warwick (1975, 1978) showed that the sclerotized remnants of the subfossil Chironomidae preserved in the stratigraphic record can be successfully used to study the development of the trophic status of lakes. The two approaches therefore are designed to answer the questions: 1) What trophic state are the lakes in at present? 2) How did they reach this state? and 3) What is their natural trophic state? Answers to these questions are critical at every specific site where some water management scheme has been advocated to reduce contamination.



An analysis of the benthic fauna and a paleoecological analysis is labour intensive and with limited manpower takes some time to complete. The project began in 1976 with collection of a sediment sample suite from all six of the Qu'Appelle Lakes. The objective of this initial stage was to characterize the deep water benthic communities in order to:

- (i) Define the trophic status of each of the six lakes in terms of the benthos.
- (ii) Compare the downstream relationship of changes in trophic status in the lake sequence.
- (iii) Provide a baseline against which future benthic studies could be compared to determine lake quality changes and the effect of water reclamation procedures being instituted throughout the Qu'Appelle watershed, including tertiary P removal.
- (iv) Provide a background knowledge of the present day benthic fauna against which the historical fauna retrieved from sediment cores can be compared.

This phase of the project is close to completion and interpretation of the results has begun (Warwick, 1970; Warwick, 1980). Based on the 1976 sample suite, a prediction was made that the excessive benthic growth in Katepwa Lake was a precollapse situation. Sampling in 1978 has shown that this predicted collapse did take place. Another aspect of the study of the present benthic community is the discovery of many deformed Chironomid larvae characterized by twisted, gnarled, asymmetrical teeth in the mentum and mandibles and thickened cuticles of the body and head capsule walls (Figure 5) (Warwick, 1980). Similar deformities in Lake Erie Chironomids were attributed to effects of toxic contaminants (Warwick, 1978).

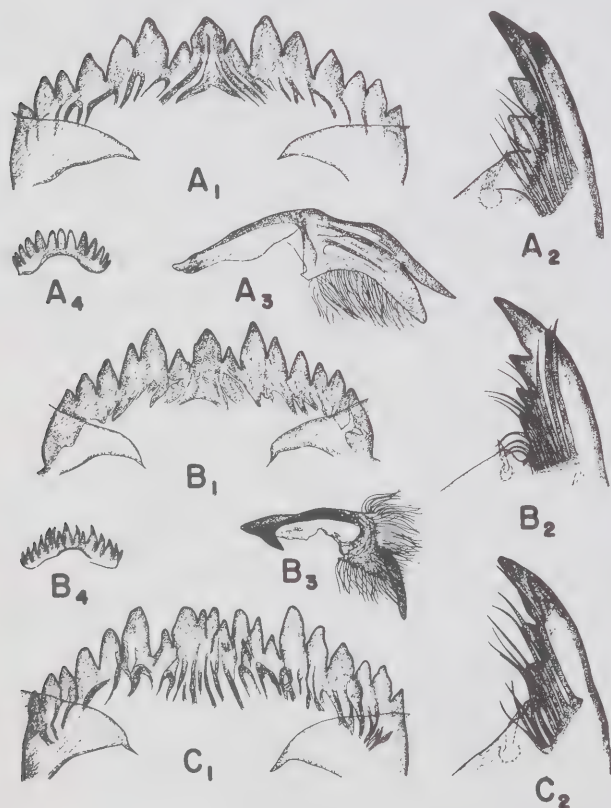


Figure 5 Comparison of mouthparts of normal (A) and deformed larvae (B and C) of Chironomus. 1, mentum; 2, apex of mandibles; 3, premandibles; 4, epipharyngeal pecten.

Also nearing completion is a preliminary analysis of trophic changes in the Qu'Appelle Lakes since 1950. This analysis is based on a comparison of the 1976 benthic fauna with samples provided to NWRI-WNR by Saskatchewan Department of Fisheries.

During February and March 1979, an extensive coring program using a MacKereth corer was carried out through the ice at Pasqua Lake. A large number of cores were collected in a traverse down the central axis of the lake. The longest core was over 100 meters and could well represent the period from 100 A.D. to the present, or longer. Preliminary analyses of selected cores have begun. Besides the use of palaeolimnology data to analyze eutrophication and contamination history, particularly by analysis of Chironomid remains, the proxy data is also expected to be of value in historical drought frequency and intensity analyses.

### Aquatic Systems and Physics

#### Mixing Processes in Shallow Prairie Lakes:

The regional physical limnology program focuses on the effects of winds on mixing of shallow, unstratified prairie lakes. There is increasing evidence that nutrient regeneration from bottom sediment is important to eutrophication in lakes. Though studies to date have concentrated on regeneration under winter ice, nutrient regeneration by physical resuspension may be crucial to the trophic state of shallow lakes on the prairies which are well exposed to wind during the ice-free period. A propensity for sediment resuspension in shallow lakes may be inferred from results which indicate that the divergence of the momentum flux is small in shallow lakes and the bottom stress is similar in magnitude to the surface stress, in contrast to deeper lakes where the bottom stress is near zero (Kenney, 1978). The physical constraints are such that a meteorological tower to study the phenomenon of wind-generated bottom stress should only be located in a large, shallow lake. For this reason and for logistical reasons (the tower instrumentation must be inspected more than once a week and the taped results translated by computer programs at NWRI and stored in the University of Manitoba computer), the prairie lake selected for study was Lake Manitoba. The tower (Diagram 2) was designed and built at NWRI-WNR in Winnipeg.

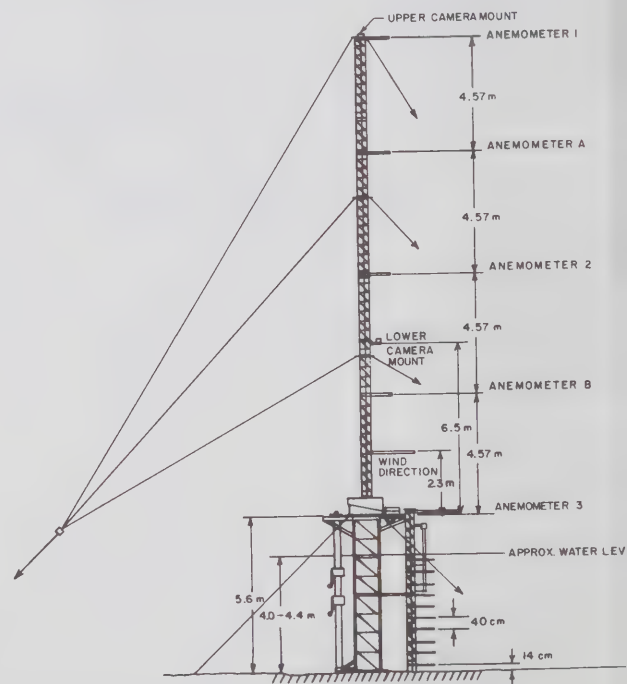
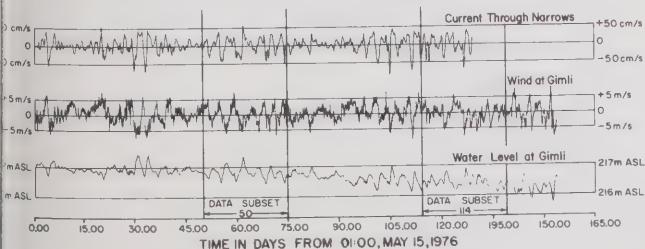


Diagram 2 Tower used in study of mixing processes in shallow prairie lakes.

The objective was to determine the degree of physical resuspension of sediment as related to the stress and various physical parameters measured on Lake Manitoba. A quantitative comparison is to be made between sediment resuspension in Lake Manitoba and Echo Lake, one of the Qu'Appelle Lakes. The study of wind-generated mixing at Lake Manitoba will also be of importance if Lake Manitoba does become the location of a future nuclear power generating station and is of relevance to the mixing of sediments carried into the lake by the Assiniboine River diversion.

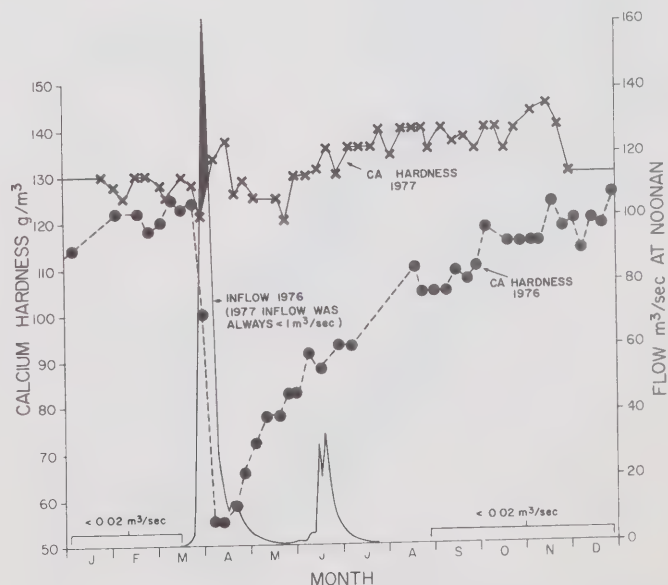
In 1979 the tower was installed in Rock Lake. This airie lake is elongated and shallow. However, it is much smaller than Lake Manitoba. The same type of measurements were made in Rock Lake during the summer of 1979 as had been made in Lake Manitoba in the previous year. This total data base is being reduced and interpreted in 1980.

A key aspect of any modelling of nutrient loading and lake productivity is the residence time of water in the lake. As mentioned previously, the south basin of Lake Winnipeg receives inputs of nutrients from the Red River. A part of this nutrient load



originates in Winnipeg sewage and suggestions have been made that removal of phosphorus from this sewage would not lower productivity in the south basin of the lake. These predictions are based on an assumed residence time in the south basin calculated from volume and all inflows. A major factor missing is this calculation of the wind-generated flux of nutrients between the south and the much larger north basins of the lake. The two basins are connected by an extremely narrow channel - the Narrows - which NWRI instrumented with current meter chains. The results (Figure 7) are such that the use of actual residence time values (or possible values) in nutrient loading-productivity models supports a conclusion that the productivity in the south basin is in proportion to nutrient input (Kenney, 1979).

During 1977 and 1978, a study of the chemical and physical controls of dissolved solids in cooling reservoirs in the prairies was conducted. In southern Saskatchewan, such cooling reservoirs are of critical importance. The International Joint Commission is involved in discussions between Montana and Saskatchewan concerning coal-fired generating stations situated on international rivers and streams. Boundary Reservoir in southeastern Saskatchewan is the major study site to date. It is the location of a large prairie region, lignite coal-fired, generating station. Research was aimed at determining the effect of the station on downstream water quality. It appears from historical data that Boundary Reservoir has actually had a beneficial and positive effect on downstream dissolved solids (Allan, 1978; Allan and Richards, 1978). The negative effects of forced evaporation on reservoir and downstream TDS appear to be largely negligible at the operating capacities up to 1977. In the long term, the efficiency of the spring flush is the major control on downstream TDS by replacing higher reservoir TDS water with much lower TDS water derived essentially from snowmelt. Reservoirs are filled (or eventually flushed in flood years) by low TDS snowmelt. Subsequently, the reservoir not only guarantees downstream flows but also guarantees flows of lower TDS by "buffering" (diluting) upstream naturally higher TDS water. The process is probably universal in prairie reservoirs. The effect is best seen in a succession of low flow, longer residence time, years when the "buffering" action is possibly enhanced by sedimentation of salts in the reservoir. In the short term, in small reservoirs such as Boundary Reservoir, TDS and major cation concentrations can rise by as much as 100 percent in the six-month period following a major runoff event (Figure 8). By comparison, evaporation (forced plus natural) is unlikely to increase concentrations by more than a maximum of 20 percent over the same time period.



75



The major source of salts during the summer period is the high TDS stream inflow. The above conclusions are substantiated by 16 years of recorded data and by the accurate long-term prediction of downstream TDS by use of a conservation of mass calculation which excluded terms for groundwater discharge and major cation sediment to water exchange. One presently controllable source of major cations to the reservoir is the release of Ca-rich sludges from thermal station demineralization plants. Although much of this Ca apparently sediments in the reservoir, it can and should be removed, especially with proposed increases in power output after 1977. Toxic metals in dredged surface sediments for Boundary Reservoir and Lake Wabamun showed possible enrichments of Zn and Cu relative to natural prairie lakes. Analyses of sediment cores indicated possible surface enrichment of Zn and Hg at Boundary and Zn, Pb, Cu, As and Cd at Wabamun. Some of these enrichments are likely to be related to power plant operation. At Lake Wabamun several deep sediment samples had very high Hg concentrations. Although probably of natural origin, investigation of these should be pursued.

Physical studies at Boundary Reservoir (Kenney, 1978) emphasized free-surface evaporation in winter in order to estimate more accurately the water loss from such prairie reservoirs. The study was based on the remote sensing of surface water temperatures in the reservoir during the winter months (Figure 9).



Figure 9 A bifurcated thermal plume showing windrows of water vapour in the air above Boundary Reservoir, Saskatchewan.

## Effects of River Diversions for Hydro-Electric Power Generation Southern Canadian Shield:

In northern Manitoba and elsewhere in the boreal forest zone of western and northern Canada, reservoirs have been created by impoundment of river water and resultant flooding of land, other reservoirs will be created in the future. Among the ecological consequences of impoundment is a short-lived upsurge in productivity owing to the leaching of nutrients from inundated land followed by a temporary depression of productivity. The reasons for the "trophic depression phase" are unknown, but recent work by Jackson and Hecky (1980) in northern Manitoba strongly suggests that the decrease in productivity is due to fixation of phosphate by certain high molecular weight fractions of soil humic matter leading into the water from flooded land (Figure 10). Even under natural conditions, dissolved phosphorus in lake and stream waters of the region is mainly bound to humic substances via iron (and probably aluminum) "bridges". Thus, control of primary production by dissolved humic matter may be a widespread and important phenomenon in both artificial and natural lakes in regions where inland waters are relatively rich in humic matter (e.g. on the Canadian Shield of western Canada). Inundation of land may accentuate the process by introducing into the water column a large amount of humic substance that is particularly effective in blocking utilization of phosphate by algae. The work of Jackson and Hecky showed, moreover, that the observed effect was not caused by light absorption or lowering of pH levels by the humic matter. The results so far are based on relatively few data from only a few bodies of water sampled only at one time of year. More work is definitely needed to confirm and extend the preliminary findings. Extension of the findings is significant because of the continuing development of hydro electric reservoirs or impoundments in the Shield area of western Canada and because of the increasing interest expressed in possible impoundment and diversion of Shield waters south to water scarce areas.

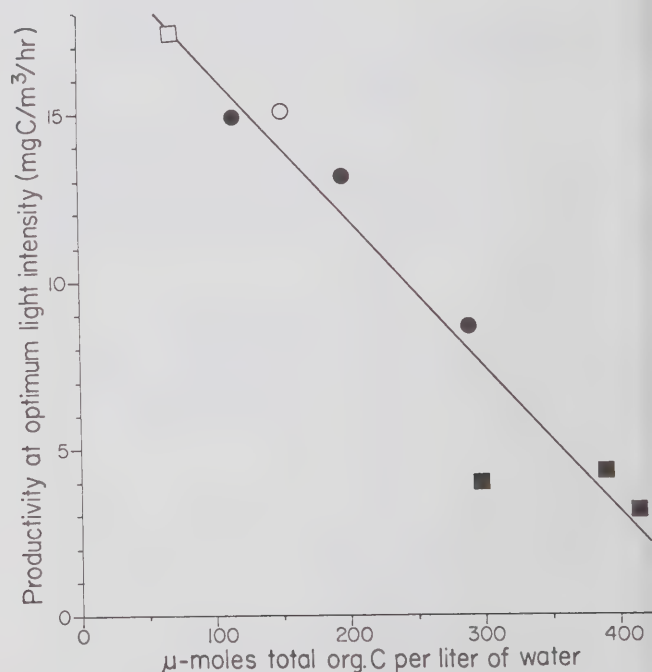


Figure 10 Reservoir productivity and total organic-C (humic content of reservoir waters), Churchill-Nelson Diversion, northern Manitoba.

## Environmental Contaminants

Present activities focus on heavy-metal pathway through rivers and lakes. The main study site of heavy-metal pathway research is the mercury polluted Wabigoon River system in northwestern Ontario (Jackson, 1979a, 1979b; Jackson and Woychik, 1980). Studies are funded from the NWRI-WNR budget and by funds provided through a Canada-Ontario agreement funded under the Canada Water Act. Other sites studied in the past, in terms of sediment sinks for heavy metals are Lake Winnipeg, the Athabasca



er system downstream from the Alberta Oil Sands deposit, and at Slave Lake (Allan and Brunskill, 1976; Allan and Jackson, 1978; Allan, 1979; respectively). Other heavy and toxic metal pathway study sites recently have been at Flin Flon (Jackson, 1978; Jackson and Woychuk, 1979) and Thunder Creek near Moose Jaw (Jackson and Woychuk, 1979).

## Heavy-Metal Sinks in Western Great Lakes

Research into heavy-metal dynamics of the great lakes in the western and northern region began with examination of sediment cores from Lake Winnipeg (Allan and Brunskill, 1976) and extended to the Athabasca River system (Allan and Jackson, 1978). The Athabasca bottom sediments were collected as part of baseline studies funded by the Alberta Oil Sands Environmental Research Program (AOSERP). Near the shores of Great Slave Lake, natural sources of heavy metals include gold and base metal deposits, mineralized greenstone belts and sedimentary bedrock, and mafic granites. Potential anthropogenic sources of heavy metals (As, Zn, Pb) include large gold and base metal extraction-processing facilities on the shores of the lake. Six sediment cores were collected on a traverse of the lake (Allan, 1978). Heavy metal concentrations and distributions are related to the regional bedrock chemistry in the drainage basin. Higher uranium concentrations in the northernmost core are attributed to extensive uraniferous rocks north of the lake (Figure 11). More subtle variations in concentration are related to sedimentologic characteristics and processes in the lake. The west basin is a natural sink for most of the heavy metals determined. Two centrally-located west-basin cores had mean zinc concentrations of 145 ppm, whereas cores closer to the north and south shores had mean concentrations of 80-100 ppm. Mn, Ni and Pb were enriched in some of the cores from the area of shallower water near the MacKenzie River outlet, rather than in the central west basin. The enrichment is related to Mn-, Ni-, and Pb-rich amorphous coatings on quartz grains. Elevated zinc and lead levels from anthropogenic activities were not detected but elevated levels are suspected for arsenic. In the two cores from the west basin, surface sediment contains up to 12 ppm arsenic, not high in comparison with noncontaminated freshwater sediments elsewhere in Canada but considerably elevated relative to concentrations of 1 ppm found deeper in the same cores.

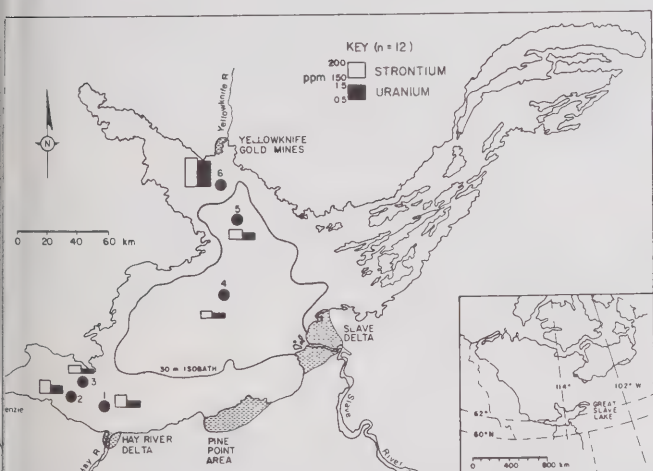


Figure 11 Uranium and strontium distribution in bottom sediments from Great Slave Lake. Values are mean for each core; 12 subsamples for each core.

## Mercury Pollution Studies in the Wabigoon River System:

Heavy metal pollutants - especially mercury - are a major threat to public health and to all forms of life, and are among the worst environmental ills in Canada today. Among the more important heavy-metal problem sites in western Canada are the lakes of the Wabigoon-English-Winnipeg River System, which are contaminated by mercury from a chloralkali plant and pulp-and-paper mill in Dryden, Ontario.

The solubility, bioavailability and toxicity of heavy-metal pollutants in lakes are thought to depend on which forms of the metals predominate in a given environment. Mercury can be mobilized in  $H_2S$ -rich sediments as an insoluble, biologically inert

sulphide, but under less highly reducing conditions it may be partially converted to the extremely toxic, water-soluble monomethyl mercury; moreover, a particular concentration of copper in water may be toxic to a certain algae or to fish if the copper is in the form of inorganic ions, but it may be harmless if the copper is complexed by dissolved humic matter.

The objectives of the research at this site are to arrive at methods of chemically restoring the system by closing off some link in the pathway of metals up the foodchain. In detail, investigations are made of heavy-metal forms in sediments, heavy-metal solubility and binding and release of metals by sediments, accumulation of metals by organisms of the foodchain (mainly plankton), and the toxicity of the metals to such organisms in different polluted freshwater environments at different times of the year. The effects of different physico-chemical factors on the mobility and biological impact of sediment-bound metals are determined.

Research in the Wabigoon River has shown that methylmercury production in polluted surface sediments is controlled by various environmental factors such as pH, sulphide, iron and manganese oxides, nutrients, humic matter, cation exchange sites and others. However, methylmercury production is independent of the total mercury concentration. Methylation is most intense at the sediment-water interface of the riverbed, regardless of the total mercury distribution (Figure 12). Methylmercury released from this interface into the water between Dryden and Clay Lake causes continual contamination of lake water, and pelagic fish such as Walleye, further downstream (Figure 13). Because of this, dredging or immobilization of the sedimentary mercury in the riverbed upstream from Clay Lake is a prerequisite to restoration of the

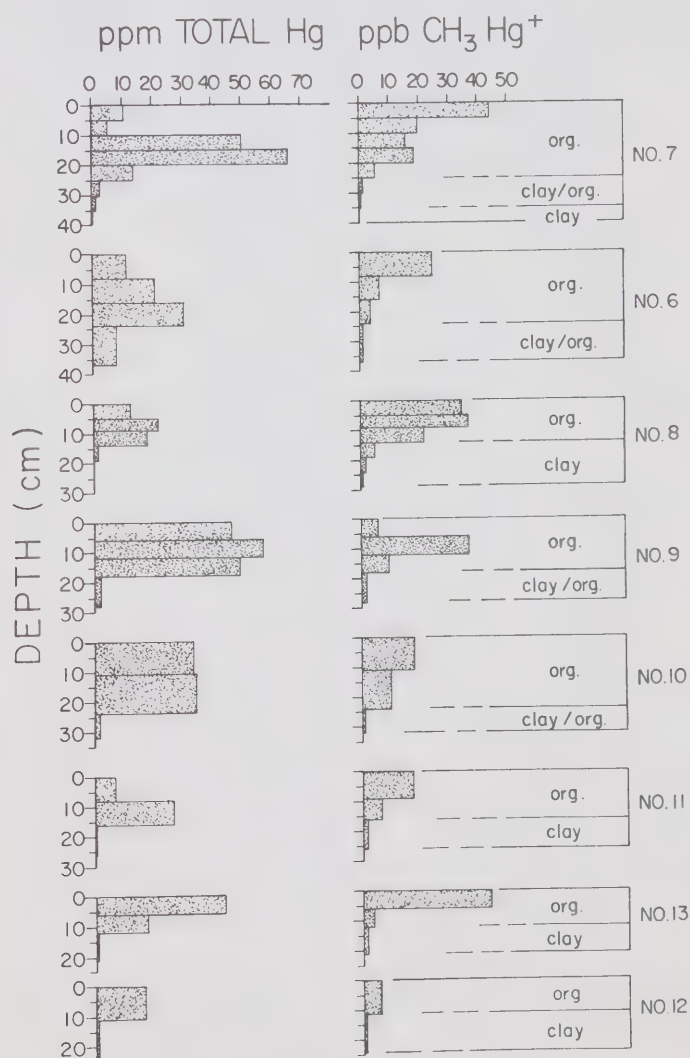


Figure 12 Total and  $CH_3-Hg^+$  in sediment cores from between Dryden and Wainwright Dam on the Wabigoon River of northwestern Ontario.

lakes of the Wabigoon-English River system. During 1979-80, the study is continuing with a program of collection and analyses of suspended sediments from the Wabigoon River. This work is being done in collaboration with the Ontario Ministry of the Environment at Thunder Bay.

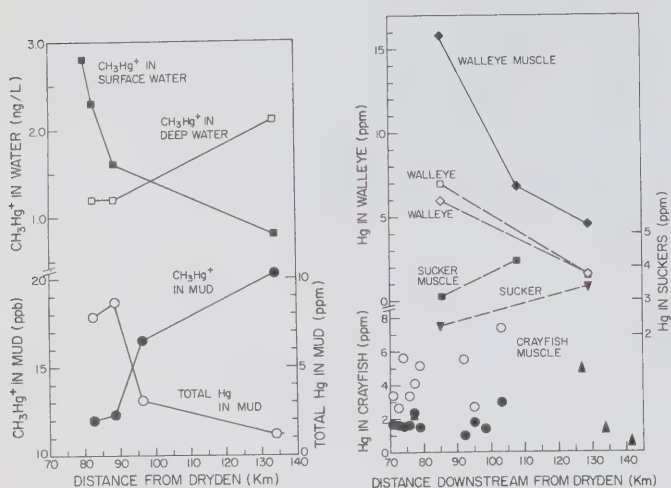


Figure 13 Variation of (A)  $\text{CH}_3\text{Hg}^+$  and total Hg in water and sediments and (B) Hg in fish and crayfish, as functions of distance from Dryden. Each point on each graph represents the mean of multiple replicate samples. Sediment and water data came from the present study; fish and crayfish data were furnished by Fimreite and Reynolds (1973), Bishop and Neary (1976), B. P. Neary (unpublished data, personal communication), Armstrong and Hamilton, (1973), and G. McRae and A. Hamilton (unpublished data, personal communication). Symbols in Figure 13 indicate year of sample collection.

Walleye:  $\blacklozenge$ , 1970;  $\diamond$ , 1975;  $\square$ , 1977.  
 Suckers:  $\blacksquare$ , 1970;  $\blacktriangledown$ , 1972.  
 Crayfish:  $\circ$ , 1971;  $\bullet$ , 1974;  $\blacktriangle$ , 1976.

#### Heavy-Metal Pollution in the Vicinity of the Flin Flon Smelter:

Results at Flin Flon (Jackson, 1978; 1979a) show that algal blooms in Shist Lake accumulate Zn from solution and sediments in a particulate form, hence the inverse relationship between dissolved and particulate Zn shown in Figure 14. This relationship may be a clue to a possible detoxification mechanism -

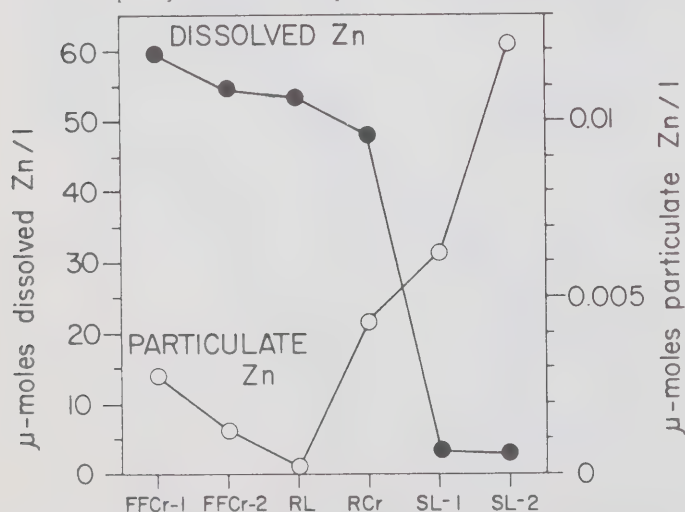


Figure 14 Variation in concentrations of dissolved ( $\bullet$ ) and particulate ( $\circ$ ) Zn in water, going downstream from FFCr-1 to SL-2.

increased productivity - of lakes contaminated by certain heavy metals. Most heavy metals are thought to be present in sediment in organically-bound form or as sulphides. Partitioning between these forms appears to be dependent on thermo-dynamic parameters of metal sulphides. Thus the artificial creation of the correct physico-chemical environment could be used as a means of precipitating heavy metals as insoluble sulphides.

#### Effect of Acidification of Heavy-Metal Cycling in Lakes:

The biogeochemistry of Hg, Zn, Co, Fe, Mn, Cr, V, Ba, Cs, As and Se, in two soft-water lakes of the Canadian Shield was investigated by means of carrier-free  $\gamma$ -emitting isotopes introduced into limnocostracans in which the pH of the water was varied from 6.8 to 5.1 (Jackson *et al.*, 1980). The residence times of radionuclides in the water were determined, and the partitioning of the nuclides among different metal-binding agents in the water and sediments was studied with the aid of membrane filtration, dialysis, solvent extractions and fractionation on Sephadex columns.

Metal behaviour varied systematically with metal properties. Metals of high crystal field stabilization energy, high electronegativity, or small ionic radius were most readily scavenged by  $>0.45 \mu\text{m}$  suspended particles and dispersed colloids in the water column and disappeared most rapidly from the water column and were preferentially accumulated by sedimentary binding agents, including organic substances. Which property of a metal had the dominant effect on metal behaviour depended on environmental factors, such as ambient pH and the nature of the binding agents. Thus Hg was removed fairly rapidly from the water at pH 6.7-6.8 owing to its high electronegativity, but was removed more slowly than any other metal at pH 5.1 owing to its large ionic radius (Figure 15).

Most metals are strongly chemisorbed or complexed by organic mud and organic ooze, and only Ba could be redissolved by cation exchange. Therefore 0.1 N NaOH and 0.1 N or 1 N HCl were inefficient extractants than  $\text{H}_2\text{O}$ , 1 N  $\text{CaCl}_2$ , or benzene/methanol, and the metals were largely nonextractable by any of these solvents. The major NaOH-extractable metal-binding agents were the high molecular weight fractions of a group of organic (probably humic) substances characterized by a UV absorption band at  $\approx 265 \text{ nm}$ . The affinity of metals for the highest molecular weight "humic" (NaOH-extractable) substances increased with electronegativity, the greatest for Hg. Hg and Se were nonextractable by HCl but the elements most readily extracted by NaOH, implying exceptionally strong covalent bonding by humic matter. The more electronegative metals were more readily extracted by HCl than by NaOH, suggesting weaker, less highly covalent bonding or preferential sorption by acid-soluble hydrated oxides.

Acidification of lake water to pH 5.1 interfered with the accumulation of Hg and other metals by organic ooze, probably owing in part to interference with the deposition or formation of complexing agents with the 265 nm absorption band. Acidification also lowered the concentration of NaOH-extractable colloidal phosphate in the ooze but had no effect on NaOH-extractable orthophosphate content.

#### Tobin Reservoir Contamination Study:

In 1980, a study of the sinks and pathways of metal and organo-chlorine contaminants in Tobin Reservoir was begun in cooperation with the Environmental Protection Service, Western Northern Region and the Soil Science Department of the University of Manitoba. During the winter of 1979-80, water, sediment and biota samples were collected at Tobin Reservoir, the main reservoir downstream from the junction of the North and South Saskatchewan Rivers. Because of its location, this is a prime site for assessment of the environmental contamination of fluvial systems in the provinces of Alberta and Saskatchewan.

#### Bow and Oldman Rivers - Fluvial Transport of Contaminants Study:

Also in 1980, a study of fluvial transport of contaminant phosphorus was initiated in the Bow and Oldman Rivers, in cooperation with Professor E. Ongley, Queens University. Dr. R. J. is liaison officer of funding through the Inland Waters Direct Research Subventions Program and the Environmental Contamination Contract Fund. The objectives are to evaluate the sediment-transport processes of phosphorus forms, heavy metals and organochlorines in both rivers. The results on the Bow River will have implications viz the tertiary treatment of Calgary effluents.



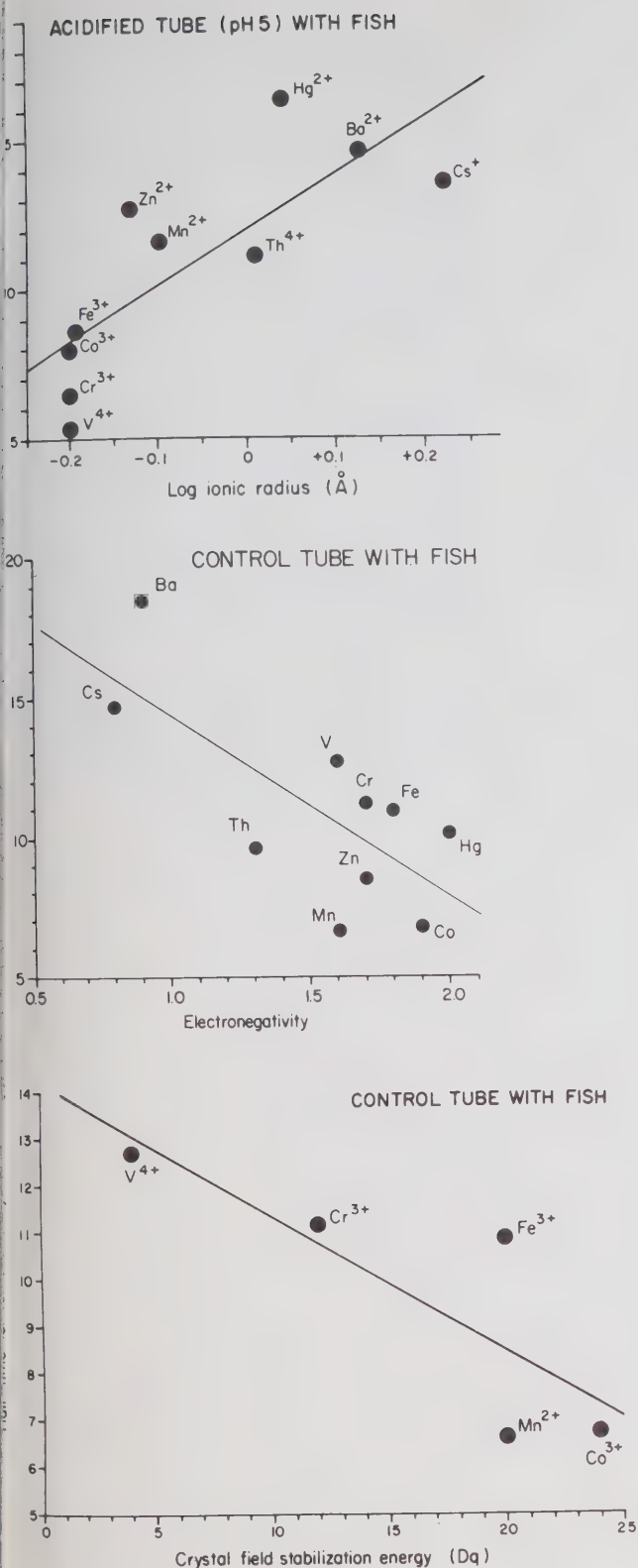


Figure 15 Relationship between metal properties and rate of disappearance of labelled metals from water column in "acidified tube" and "control tube with fish". A, half-time for metal removal in acidified tube plotted against ionic radius (semilog plot;  $r=0.790$ ;  $P=0.001-0.01$ ); B, half-time for metal removal in control tube with fish plotted against electronegativity ( $r=-0.731$ ;  $P=0.01-0.02$ ); C, half-time for metal removal in control tube with fish plotted against crystal field stabilization energy, on assumption of octahedral coordination in "strong field" ( $r=-0.823$ ;  $P=0.05-0.1$ ). (Transition metals only).

## References Cited

- R. J. Allan "Natural controls of dissolved solids in Boundary Reservoir, Saskatchewan." *Can. Water Res. Jour.* Vol. 3, No. 3, pp. 78-96, 1978.
- R. J. Allan "Regional geochemical anomalies related to plate tectonic models for the northwestern Canadian Shield." *Jour. Geochem. Explor.* Vol. 10, pp. 203-218, 1978.
- R. J. Allan "Sediment related fluvial transmission of contaminants: some advances by 1979." *Environment Canada, Scientific Series, No. 107*, 24 pp., 1979.
- R. J. Allan "Heavy metals in bottom sediments of Great Slave Lake (Canada) a reconnaissance." *Environmental Geology*, Vol. 3, pp. 49-58, 1979.
- R. J. Allan "The inadequacy of existing chlorophyll-1/phosphorus concentration correlations for assessing remedial measures for hypertrophic lake." *Environmental Pollution, Series, B*, Vol. 1, pp. 41-55, 1980.
- R. J. Allan  
G. J. Brunskill "Relative atomic variation of elements in lake sediments: Lake Winnipeg and other Canadian lakes." In *Interactions between Sediments and Freshwater*, Pub. Junk and Pudoc: pp. 108-120, 1976.
- R. J. Allan  
T. A. Jackson "Heavy metals in bottom sediments of the main-stream Athabasca River system in the Alberta Oil Sands Environmental Research Programme Study Area." *Alberta Oil Sands Environmental Research Programme, AOSERP Report, No. 34*, 72 pp., 1978.
- R. J. Allan  
P. C. Kenney "Rehabilitation of eutrophic Prairie lakes in Canada." *Verh. Int. Ver. Limnol.*, Vol. 20, pp. 214-224, 1977.
- R. J. Allan  
M. Roy "Lake water nutrient chemistry and chlorophyll-a in Pasqua, Echo, Mission, Katepwa, Crooked and Round Lakes on the Qu'Appelle River, Saskatchewan." *Environment Canada, Scientific Series, No. 112*, 66 pp., 1980.
- R. J. Allan  
J.D.H. Williams  
S. R. Joshi  
W. F. Warwick "Historical changes and relationship to internal loading of phosphorus forms in hypertrophic Prairie lakes." *Jour. Environmental Quality*, Vol. 9, pp. 199-206, 1980.
- P. Cross "The application of nutrient loading-productivity models to the Qu'Appelle Valley Lakes." *NWRI-WNR, PR-78-1*, 1978.
- R. W. Durham  
S. R. Joshi  
R. J. Allan "Radioactive dating of sediment cores from four contiguous lakes in Saskatchewan, Canada." *Science of the Total Environment*, Vol. 15, No. 1, pp. 65-71, 1980.
- T. A. Jackson "The biogeochemistry of heavy metals in polluted lakes and streams at Flin Flon, Canada and a proposed method for limiting heavy metal pollution of natural waters." *Environ. Geology*, Vol. 2, pp. 173-189, 1978.
- T. A. Jackson "Relationships between the properties of heavy metals and their biogeochemical behaviour in lakes and river-lake systems." *Proc. Internat. Conf. on Heavy Metals in the Environment*, London, 1969. Pub. CEP Consultants, Edinburgh, Scotland, pp. 457, 560, 1979.
- T. A. Jackson "Sources of heavy metal contamination in a river-lake system." *Environmental Pollution*, Vol. 18, pp. 131-138, 1979.
- T. A. Jackson  
R. E. Hecky "Depression of primary productivity by humic matter in lake and reservoir waters of the boreal forest zone." *Canadian Jour. of Fisheries and Aquatic Sciences* (In press, 1980).



- T. A. Jackson "Experimental study of trace metal chemistry in softwater lakes at different pH levels." *Can. Jour. Fisheries and Aquatic Sciences*, Vol. 37, pp. 387-402, 1980.
- G. Kipphut
- R. H. Hesselein
- D. W. Schindler
- T. A. Jackson "A preliminary report on the geochemistry of mercury in polluted sediments of Thunder Creek, Saskatchewan." NWRI-WNR, PR-79-3, 1979.
- R. N. Woychuk
- T. A. Jackson "The geochemistry and distribution of mercury in the Wabigoon River system." In *Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures: A Progress Report for 1979-1980*. Ed. T. A. Jackson, 28 pp., 1980.
- R. N. Woychuk
- B. C. Kenney "Generation and scaling of surface streaks in wind-wave tunnel." NWRI-WNR, PR-76-2, 1976.
- B. C. Kenney "An experimental investigation of the fluctuating currents responsible for the generation of windrows." Ph.D. Thesis, Univ. of Waterloo, 163 pp., 1978.
- B. C. Kenney "Some physical effects of thermal effluents in Boundary Dam Reservoir, Saskatchewan, during winter." *Can. Water Resources Jour.*, Vol. 3, No. 3, pp. 97-100, 1978.
- B. C. Kenney "Lake surface fluctuations and the mass flow through the Narrows of Lake Winnipeg." *Jour. Geophys. Res.*, Vol. 84, pp. 1225-1235, 1979.
- G. Laksham "A study of phosphate contribution to the Fish Lakes from the shoreline cottages in the Qu'Appelle Basin." NWRI-WNR, PR-79-2, 1979.
- W. F. Warwick "Man and the Bay of Quinte, Lake Ontario: 2,800 years of cultural influence, with special reference to the Chironomidae (Diptera), Sedimentation and Eutrophication." Ph.D. Thesis, Univ. of Manitoba, 288 pp., 1978.
- W. R. Warwick "Palaeolimnology of Pasqua Lake: a preliminary report on benthic fauna responses to the sedimentation in the water environment and long core collection during February-March, 1969." NWRI-WNR, PR-79-4, 1979.
- W. F. Warwick "Pasqua Lake southeastern Saskatchewan: preliminary assessment of trophic status and contamination based on the Chironomidae (Diptera)." In *Chironomidae Ecology, Systematics, Cytology and Physiology*. Ed. D. A. Murray, Pergamon Press, pp. 255-267, 1980.
- W. F. Warwick "Chironomidae (Diptera) responses to 2,800 years of cultural influence: a palaeolimnological study with special reference to sedimentation, eutrophication and contamination processes." *Canadian Entomologist*, (In press, 1980).
- W. F. Warwick "Man and the Bay of Quinte, Lake Ontario: 2,800 years of cultural influence, with special reference to the Chironomidae (Diptera), sedimentation and eutrophication." *Bull. of the Canadian Jour. Fisheries and Aquatic Sciences*, (In press, 1980).

## PUBLICATIONS





# SENIOR SCIENTIST

- A. Vollenweider "Il Problema dell'eutrofizzazione delle acque costiere dell Emilia Romagna: situazione e prospettive; (The eutrophication problem of the coastal waters of Emilia-Romagna)." Rapporto finale dell ricerche condotte nel 1977. (book), 182 pp., 1979.
- A. Vollenweider "Das Nährstoffbelastungskonzept als Grundlage für den externen Eingriff in den Eutrophierungsprozess stehender Gewässer und Talsperren." (The concept of nutrient load as a basis for the external control of the eutrophication process in lakes and reservoirs.) Zeit. Wasser und Abwasser Forschung, Vol. 12, No. 2, pp. 45-56, 1979.
- A. Vollenweider "Phosphorus loading concept and Great Lakes eutrophication" (with W. Rast and J. J. Kerekes). Proc. 11th Annual Cornell University Conference: Phosphorus Management Strategies for the Great Lakes, Rochester, N. Y., April, pp. 207-234, 1979.
- A. Vollenweider "L'eutrofizzazione: Il Problema in Scala Mondiale." (Eutrophication: a global problem.) In: Atti del Convegno sulla Eutrofizzazione in Italia, Roma 3-4 Ottobre, 1978. Consiglio Nazionale delle Ricerche AC/2/45-70. Roma 1979. 7-26.

## WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

- Barabas "Implementing GEMS/WATER" ("Mise en oeuvre du GEMS/EAU") - A Progress Report (editorial). Water Quality Bulletin, Vol. 4, No. 1, p. 2, January 1979.
- Barabas "The United Nations and the Environment" (Les nations unies et l'environnement") (editorial). Water Quality Bulletin, Vol. 4, No. 2, p. 2, April 1979.
- Barabas "The great rivers - problems and opportunities" ("Les grand fleuves - problemes et possibilites") (editorial). Water Quality Bulletin, Vol. 4, No. 3, p. 3, July 1979.
- Barabas "Un programme des nations unies pour la surveillance de l'environnement." Une conférence invitée à la conférence "Les contaminants dans l'environnement" organisée par le Ministère de la Pêche et L'Environnement Canada, Québec, 14-16 mai, 1979.

## AQUATIC ECOLOGY DIVISION

- J. Bloesch  
N. M. Burns "A critical review of sediment trap techniques." Schweiz. Z. Hydrol., Vol. 42 (in press, 1980).
- B. K. Burnison "Modified DMSO extraction for chlorophyll analysis of phytoplankton." Can. J. Fish. Aquat. Sci., Vol. 37, pp. 729-733, 1980.
- N. M. Burns  
F. Rosa "In situ measurement of the settling velocity of organic carbon particles and ten species of phytoplankton in Lake St. George." Limnology & Oceanography, Vol. 25 (in press, 1980).
- M. N. Charlton "Oxygen depletion in Lake Erie: Has there been any change?" Can. J. Fish. Aquat. Sci., Vol. 37, pp. 72-81, 1980.
- M. N. Charlton "Hypolimnion oxygen consumption in lakes: Discussion of Productivity and Morphometric Effects." Can. J. Fish. Aquat. Sci., Vol. 37, pp. 1531-1539, 1980.

- M. N. Charlton "Oxygen depletion in the central basin of Lake Erie: Has there been any change?" IWD Scientific Series, No. 110, 14 pp., & 2 appendices, 1979.
- H.F.H. Dobson "Observed phosphorus in Lake Ontario." Great Lakes Focus on Water Quality, Vol. 6, pp. 5-7, 1980.
- R. Frank  
G. J. Sirons  
R. L. Thomas  
R. K. McMillan "Triazine residues in suspended solids (1974-1976) and water (1977) from the mouths of Canadian streams flowing into the Great Lakes." J. Great Lakes Res., Vol. 5, 131 pp., 1979.
- W. A. Glooschenko "Coastal ecology of the Hudson/James Bay area." Zeit. Geomorph. N.F., Suppl.-Bd., Vol. 34, pp. 214-224, 1980.
- W. A. Glooschenko "Coastal salt marshes of Canada." Proc. 2nd Wetlands Sympos., Saskatoon, 9 pp., 1980.
- W. A. Glooschenko  
J. A. Capobianco "Geochemistry of a subarctic salt marsh." Marine Geology (in press, 1980).
- W. A. Glooschenko  
R. Sims  
M. Gregory  
T. Mayer "The use of bog vegetation as a monitor of atmospheric input of metals." In: Atmospheric Input of Pollutants to Natural Water (S. Eisenreich, Ed.), Ann Arbor Science Publ. (in press, 1980).
- B. T. Hargrave  
N. M. Burns "Assessment of sediment trap collection efficiency." Limnology & Oceanography, Vol. 24, pp. 1124-1135, 1979.
- D.R.S. Lean "Eutrophication: Considerations for nutrient removal." Published in Proceedings from Nutrient Control Technology Seminar, Calgary, Alberta, Feb. 7-8, 1980.
- D.R.S. Lean  
B. K. Burnison "An evaluation of errors in the C method of primary production measurement." Limnology & Oceanography, Vol. 24, pp. 917-928, 1980.
- P. G. Manning  
L. A. Ash "Mossbauer spectral studies of pyrite, ferric, and high-spin ferrous distributions in sulphide-rich sediments from Moira Lake, Ontario." Can. Mineral, Vol. 17, pp. 111-115, 1979.
- P. G. Manning  
W. Jones  
T. Birchall "Mossbauer spectral studies of iron-enriched sediments from Hamilton Harbour, Ontario." Can. Mineral. Accepted.
- P. G. Manning  
J.D.H. Williams  
M. N. Charlton  
L. A. Ash  
T. Birchall "Mossbauer spectral studies of the diagenesis of iron in a sulphide-rich sediment core." Nature, Vol. 280, pp. 134-136, 1979.
- I. P. Martini  
R.I.G. Morrison  
W. A. Glooschenko "Coastal studies in James Bay, Ontario." Geosci. Can., Vol. 7, pp. 11-21, 1980.
- A. Massalski  
G. G. Leppard "A survey of some Canadian lakes for the presence of ultrastructurally discrete particles in the colloidal size range." J. Fish. Res. Bd. Can., Vol. 36, pp. 906-921, 1979.
- A. Massalski  
G. G. Leppard "A morphological examination of fibrillar colloids associated with algae and bacteria in lakes." J. Fish. Res. Bd. Can., Vol. 36, pp. 922-938, 1979.
- P. A. Meyers  
R. A. Bourbonniere  
N. Takeuchi "Southern Lake Huron: hydrocarbons and fatty acids in sediments." Special Report No. 72, Great Lakes Research Division, The University of Michigan, 65 pp., August 1979.

- P. A. Meyers  
H. B. Maring  
R. A. Bourbonniere
- "Alkane and alkanolic acid variations with depth in modern sediments from Pyramid Lake." *Advances in Organic Geochemistry*: (in press, 1979).
- T. P. Murphy
- "Ammonia and nitrate uptake in the Lower Great Lakes." *Can. J. Fish. Aquat. Sci.*, Vol. 37, pp. 1365-1372, 1980.
- J. O. Nriagu
- "Global inventory of natural and anthropogenic emissions of trace metals to the atmosphere." *Nature*, Vol. 279, pp. 409-411, 1979.
- J. O. Nriagu
- "The global cycle of cadmium." In: *Cadmium in the Environment* (J. O. Nriagu, Ed.), New York, Wiley & Sons, Vol. 1, pp. 1-12, 1980.
- J. O. Nriagu
- "Production, uses and properties of cadmium." In: *Cadmium in the Environment*, (J. O. Nriagu, Ed.), New York, Wiley & Sons, Vol. 1, pp. 35-70, 1980.
- J. O. Nriagu
- "Cadmium in the atmosphere and precipitation." In: *Cadmium in the Environment* (J. O. Nriagu, Ed.), New York, Wiley & Sons, Vol. 1, pp. 71-114, 1980.
- J. O. Nriagu
- "Human health risks from lead in ambient air." In: *Toxicity of Lead* (R. L. Singhal and J. A. Thomas, Eds.), Baltimore, Urban & Schwarzenberg, pp. 483-503, 1980.
- J. O. Nriagu  
R. D. Coker
- "Trace metals in humic and fluvic acids from Lake Ontario." *Environ. Sci. Technol.*, Vol. 14, pp. 443-446, 1980.
- J. O. Nriagu  
R. D. Coker  
A.L.W. Kemp
- "Thiosulfate, polythionate and rhodanese activity in Lakes Erie and Ontario sediments." *Limnology & Oceanography*, Vol. 24, pp. 383-389, 1979.
- J. O. Nriagu  
A.L.W. Kemp  
H.K.T. Wong  
N. Harper
- "Sedimentary record of heavy metal pollution in Lake Erie." *Geochim. Cosmochim. Acta.*, Vol. 43, pp. 247-258, 1979.
- B. G. Oliver  
D. B. Shindler
- "Trihalomethanes from the chlorination of aquatic algae." *Environmental Science & Technology* (in press, 1980).
- S. Painter
- "Identification manual for banned aquatic plants." *Environment Canada*, 1979.
- D. B. Shindler  
L. M. Prescott
- "Improvements on the Prescott-Jones method for the colorimetric analysis of ureido compounds." *Analyt. Biochem.*, Vol. 97, pp. 421-422, 1979.
- D. B. Shindler  
H. W. Paerl  
P. E. Kellar  
D.R.S. Lean
- "Environmental constraints on *Anabaena* nitrogen- and carbon-fixation: effects of hyperoxia and phosphate depletion during blooms and in chemostats." *Proc. SIL Workshop on Hypertrophic Ecosystems*, Junk Publ., Netherlands (in press, 1980).
- W.M.J. Strachan  
W. A. Glooschenko  
R. J. Maguire
- "Environmental impact and significance of pesticides." Chapter 1, In: *Water Pollution: Chemical Analysis*, Vol. 3: Pesticides and Herbicides. CRC Press (in press, 1980).
- R. T. Wright  
B. K. Burnison
- "Heterotrophic activity measured with radio-labelled organic substrates." In: *Native Aquatic Bacteria: Enumeration, Activity & Ecology* (Costerton & Cowell, Eds.), pp. 140-155, 1979.
- F. M. Boyce
- "On the possibilities of thermal energy conversion in lakes." *Atmosphere Ocean* (in press, 1979).
- F. M. Boyce
- Comments on "rotating hydraulics in deep water channel flow" by Lars Rydberg. *Tellus*, Vol. 32, pp. 90-92, 1980.
- F. M. Boyce  
F. Chocchio  
B. Eid  
F. Penicka  
F. Rosa
- "Hypolimnion flow between the Central and Eastern Basins of Lake Erie during 1980." *Great Lakes Res.* (in press, 1979).
- W. P. Budgell  
A. El-Shaarawi
- "Time series modelling of storm surges on medium-sized lake." *Marine Forecasting* (Predictability and Modelling in Ocean Hydrodynamics). Elsevier Oceanography Series, Vol. 25, pp. 197-218, 1979.
- R. P. Bukata  
J.H. Jerome  
J. E. Bruton  
S. C. Jain
- "Determination of inherent optical properties of Lake Ontario coastal waters." *Applied Optics*, Vol. 18, pp. 3926, 1979.
- R. P. Bukata  
J. E. Bruton  
J. H. Jerome
- "Conceptual approach to the simultaneous determination of the backscatter and adsorption coefficients of natural waters." *Applied Optics*, Vol. 19, p. 1550, 1980.
- R. P. Bukata  
J. H. Jerome  
J. E. Bruton  
S. C. Jain
- "Nonzero subsurface irradiance reflectance at 670 nm. from Lake Ontario water masses." *Applied Optics*, Vol. 19, p. 2487, 1980.
- S. C. Jain  
H. H. Zwick  
W. D. McColl  
R. P. Bukata  
J. H. Jerome  
Canada Centre for Inland Waters
- "A combined CZCS, aircraft, and in situ water quality remote sensing experiment in Lake Ontario." *Ocean Optics VI*, ed. S. C. Duntley, SPIE Vol., p. 208, 1980.
- "Assessment of water quality assessment capability for Lake Ontario." *Scientific Series No. 111*, Inland Waters Directorate National Water Research Institute. Project Leader, T. J. Simons; contributions from M. Boyce, A. S. Fraser, E. Halfon, D. Hyde, D.C.L. Lam, W. M. Scherzer, A. H. El-Shaarawi, T. J. Simons and K. Wilson.
- F. C. Elder
- "Atmospheric Inputs." Chapter 5.0 *Great Lakes Water Quality*, Appendix B, Surveillance Committee Report, International Joint Commission, 1979.
- F. C. Elder  
M. E. Thompson
- "Sensitivity of the Canadian aquatic regime to damage by long-range transport of pollutants." Contained in "The LRTAP Problem in North America: a preliminary overview", United States-Canada Research Consultation Group on Long-Range Transport of Air Pollutants, Dept. of External Affairs, 1979.
- A. S. Fraser
- "Changes in Lake Ontario total phosphorus concentrations 1976-1978." *J. Great Lakes Res.*, Vol. 6, No. 1, pp. 83-87, 1980.
- R. Gottinger
- "Computerized Chart Reproduction for Scientific Applications." *Lighthouse*, J. the Canadian Hydrographers' Association, Edition No. 20, pp. 4-7, November 1979.
- E. Halfon
- "Mathematical modelling of phosphorus dynamics through integration of experimental work and system theory." In: *Perspectives in Lake Ecosystems Modelling* (D. Scavia and J. Robertson, Eds.), Ann Arbor Science Publications, Ann Arbor, pp. 75-83, 1979.

#### AQUATIC PHYSICS AND SYSTEMS DIVISION

- M. B. Beck  
E. Halfon  
G. Van Straten
- "The propagation of errors and uncertainty in forecasting water quality." IIASA working paper, WP-74-100, 1979.



- Halfon "Preview: Theory in ecosystems modelling." In: Theoretical Systems Ecology: Advances and Case Studies (E. Halfon, Ed.), Academic Press, New York, pp. 1-15, 1979.
- Halfon "The effects of data variability in the development and validation of ecosystem models." In: Methodology in Systems Modelling and Simulation (B. P. Zeigler, M. S. Elzas, G.J. Klir and T. I. Oren, Eds.), North Holland Publishing Company, pp. 335-343, 1979.
- Halfon "Computer-based development of large scale ecological models: problems and prospects." In: Systems Analysis of Ecosystems (G. S. Innis, ed.), pp. 197-209, 1980.
- Halfon "On the parameter structure of a large-scale ecological model." In: Contemporary Quantitative Ecology and Related Econometrics (G. P. Patil and M. Rosenweig, Eds.), pp. 274-293, 1980.
- Halfon "Model order estimation and system identification theory and application to the modelling of  $^{32}\text{P}$  kinetics within the trophogenic zone of a small lake." Ecological Modelling, Vol. 6, pp. 1-22, 1979.
- Unbehauen  
Schmid
- F. Hamblin "Great Lakes storm surge." J. of Great Lakes Res., Vol. 5, No. 3-4, pp. 312-315, 1979.
- C.L. Lam "Finite element simulation of anisotropic turbulent diffusion in lakes." Proc. 3rd Int. Conf. on Finite Elements in Water Resources (Invited lecture), U. of Mississippi, Oxford, May 19-23, pp. 3.20-3.35, 1980.
- C.L. Lam "Temporal and spatial constraints in data estimation problems." J. Appl. Math. Notes, 10 pp. (in press, 1980).
- C.L. Lam  
R. Murthy  
C. Miners "An inverse problem approach to modelling coastal effluent plumes." J. Advances in Water Resources, 14 pp. (in press, 1980).
- C.L. Lam  
W. M. Schertzer "Modelling the interaction of climate and aquatic regimes of large lakes." Proc. of the Canadian Climate Program Water Workshop, Edmonton, Alberta, Feb. 28-29, 6 pp. (in press, 1980).
- R. Murthy  
C. Miners "Meandering effects on the diffusion of continuous plumes in coastal currents." J. Great Lakes Res., Vol. 6, No. 1, pp. 88-93, 1979.
- R. Murthy  
N. N. Filatov "Variability of currents and horizontal turbulent exchange coefficients in Lakes Huron and Ontario (North America) and Lake Ladoga (USSR)." J. Physics of Atmosphere and Oceans, Academy of Sciences of USSR, 1979.
- W. M. Schertzer  
E. B. Bennett  
F. Chiocchio "Water balance estimate for Georgian Bay in 1974." Water Resources Res., Vol. 15, No. 1, pp. 77-84, 1979.
- K. R. Shah  
A. H. El-Shaarawi "Interval estimation in models with distributed lags." To appear in the proceedings of the Symposium on Multivariate Data Analysis held in Halifax, (R. E. Gupta, Ed.), October 1979.
- T. J. Simons "Circulation models of lakes and inland seas." Can. Bull. Fish. Aquat. Sci., Bulletin 203, 1980.
- T. J. Simons  
D.C.L. Lam "Some limitations of water quality models for large lakes: a case study of Lake Ontario." Water Resources Res., Vol. 16, pp. 105-116, 1980.
- W.M.J. Strachan  
H. Hunneault  
W. M. Schertzer  
F. C. Elder "Organochlorines in precipitation in the Great Lakes region." In: Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment (B. K. Afghan and D. Mackay, Eds.), New York and London, Plenum Press, pp. 387-396, 1980.
- M. E. Thompson  
F. C. Elder  
A. R. Davis  
S. Whitlow "Evidence of acidification of rivers of eastern Canada." Proc. Int. Conf. on the Ecological Impact of Acid Precipitation, Sandefjord, Norway, March 1980.

#### ANALYTICAL METHODS DIVISION

- B. K. Afghan  
D. Mackay "Analysis of hydrocarbons and halogenated hydrocarbons." Plenum Press, New York, 1979.
- H. Agemian  
J. D. DaSilva "Automatic method for the determination of total mercury in fresh and saline waters and sediment." Analytica Chimica Acta, Vol. 104, pp. 285-291, 1979.
- H. Agemian  
A.S.Y. Chau "Interlaboratory quality control study no. 24. Eight phenotypic acid herbicides in natural water." IWD Report Series, (in press, Ottawa, Ontario).
- L. Babjak  
A.S.Y. Chau "Evaluation of 14 charcoal-polynethan foam mixtures for the separation of mirex and photomirex from aroclor 1254." J. Assoc. Off. Anal. Chem., Vol. 62, p. 1174, 1979.
- T. Bistricki "Prevention of losses during X-ray microanalysis." Scanning Electron Microscopy/1979/II, SEM Inc., AMF O'Hara, IL 60666, U.S.A.
- T. Bistricki "A pellet mould for bulk special X-ray microanalysis in SEM." J. of Micro., Vol. 119, Pt. 1, 1980.
- T. Bistricki  
A. Mudroch "X-ray microanalysis of precipitates from an elutriate test filtrate." Proc. 7th Annual Meeting MSC, 1980.
- A.S.Y. Chau "Analysis of mirex in sediment - problems and solutions." In: Hydrocarbon and Halogenated Hydrocarbon in Aquatic Environment (B. K. Afghan and D. Mackay Eds.), Plenum Press, New York and London, 1979.
- A.S.Y. Chau "One of the associated editors in 'Hydrocarbon and halogenated hydrocarbons in the aquatic environment.'" (B. K. Afghan and D. Mackay, Eds.), Plenum Press, New York and London, 1979.
- A.S.Y. Chau  
L. J. Babjak "Column chromatographic determination of mirex, photomirex and polychlorinated biphenyls in lake sediments." J. Assoc. Off. Anal. Chem., Vol. 62, p. 107, 1979.
- A.S.Y. Chau  
H. B. Lee "Analytical reference materials III. Preparation and homogeneity test of large quantities of wet and dry sediment reference materials for long term PCB quality control studies." J. Assoc. Off. Anal. Chem., Vol. 63 (in press, 1980).
- A.S.Y. Chau  
R. Thomson "Analytical reference materials I. Preparation and purification of photomirex." J. Assoc. Off. Anal. Chem., Vol. 62, p. 1302, 1979.
- A.S.Y. Chau  
J. Carron  
H. B. Lee "Analytical reference materials II. Preparation and sample integrity of homogeneous fortified wet sediment for polychlorinated biphenyl quality control studies." J. Assoc. Off. Anal. Chem., Vol. 62, p. 1312, 1979.



- V. I. Colini  
J. P. Sherry
- "Chironomus plumosus (Diptera: chironomidae) from Lake Ontario parasitized by a mermithid nematode with subsequent colonization by a saprolegniaceous fungus." Trans. Amer. Micros. Soc., Vol. 98, No. 4, pp. 572-576, 1979.
- B. J. Dutka
- "Microbial indicators, problems and potential of new microbial indicators of water quality." In: Biological Indicators of Water Quality (A. James and L. Evison, Eds.), John Wiley & Sons New York, pp. 18-1, 18-24, 1979.
- B. J. Dutka  
K. K. Kwan
- "Comparison of eight media procedures for recovering fecal streptococci from water under winter conditions." J. Appl. Bact., Vol. 45, pp. 333-340, 1979.
- B. J. Dutka  
S. Kuchma  
K. K. Kwan
- "Fecal coliform and *E. coli* estimates, tip of the iceberg." Water, Air and Soil Pollution, Vol. 11, pp. 349-362, 1979.
- B. J. Dutka  
K. D. Switzer-Howse
- "Distribution of mutagens and toxicants in Lake Ontario waters as assessed by microbiological procedures." J. Great Lakes Res., Vol. 4, pp. 237-241, 1979.
- B. J. Dutka  
A. A. Qureshi  
I. Rybakowski  
S. Tobin
- "Microbiological characteristics of urban storm water runoffs in central Ontario." Research Report 87, Canada-Ontario Agreement on Great Lakes Water Quality, Ministry of Supply and Services, Canada, Cat. No. EN 43-11/87, Training and Technology Transfer Division, EPS, Ontario, 1978.
- L. Kalas  
A. Mudroch  
F. I. Onuska
- "Bioaccumulation of organochlorine and arene pollutants by *Cipango-paludina chinensis* (mollusca: gastropoda) from ponds in the Botanical Gardens, Hamilton, Ontario." Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment (B. K. Afghan and D. Mackay, Eds.), Plenum Press, pp. 567-576, 1979.
- J. Lawrence
- "Semi-quantitative determination of fulvic acid, tannin and lignin in natural waters." Water Res., Vol. 14, pp. 373-377, 1979.
- H. B. Lee  
A.S.Y. Chau
- "National Q.C. studies No. 25 on PCB's in wet sediment." Inland Waters Directorate Report Series (in press, 1979).
- M. J. McGlinchey  
B. G. Sayer  
F. I. Onuska  
M. E. Comba
- "A carbon-13 and proton nuclear magnetic resonance study 5,6 dihydro-2 methyl - 1,4 oxathiin derivatives." J. Chem. Soc. (Perkins Transactions II), pp. 1267-1271, 1979.
- M. Munawar  
T. Bistricki
- "Scanning electron microscopy of some nanoplankton cryptomonads." Scanning Electron Microscopy/1979/III, SEM Inc., AMF O'Hara, IL 60666, U.S.A.
- M. Munawar  
T. Bistricki
- "Morphological characteristics of pure ultraplankton from Lake Superior by scanning electron microscopy." Proc. 7th Annual Meeting MSC, 1980.
- B. G. Oliver
- "Haloforms in drinking water: a study of precursors and precursor removal." J. Am. Water Works Assoc., Vol. 71, No. 3, pp. 161-163, 1979.
- F. I. Onuska
- "Poly ( -olefins) - a novel non-polar stationary phase for gas chromatography." J. Chromatogr., Vol. 186, pp. 259-271, 1979.
- F. I. Onuska
- "Capillary column gas chromatography. Twenty year old and still in the developing stage?" Can. Res. & Develop., Vol. 12, pp. 26-33, 1979.
- F. I. Onuska  
M. E. Comba
- "Identification and quantitative analysis of polychlorinated biphenyls on WCOT glass capillary columns." In: Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment (B. K. Afghan and D. Mackay, Eds.), Plenum Press, pp. 285-302, 1979.
- P. Picket  
K. Jamati  
P. D. Goulden
- "Preservation du contenu en O-phosphore d'échantillons d'eau du fleuve Saint-Laurent." Water Res., Vol. 13, pp. 1187-1191, 1979.
- A. A. Qureshi  
B. J. Dutka
- "Storm runoff microbiology adds to concerns." Water and Sewage Works, Vol. 13, No. 3, pp. 86-88, 1979.
- A. A. Qureshi  
B. J. Dutka
- "Microbiological studies on the quality of urban stormwater in southern Ontario, Canada." Water Res., Vol. 13, No. 10, pp. 977-985, 1979.
- S. S. Rao
- "Surface distributions of aerobic heterotrophs and their relation to temperature and nutrients." J. Great Lakes Res., Vol. 4, pp. 401-414, 1979.
- S. S. Rao  
A. A. Jurkovic
- "Relationship between bacterial population and oxygen levels in the Central Basin of Lake Erie." J. Great Lakes Res., Vol. 5, pp. 225-228, 1979.
- S. S. Rao  
R. E. Kwiatkowski  
A. A. Jurkovic
- "Distribution of bacteria and chlorophyll *a* at a nearshore station in Lake Ontario." Hydrobiologia, Vol. 66, pp. 33-39, 1979.
- E. F. Scott  
E. Nagy  
J. P. Sherry  
B. J. Dutka  
V. Glooschenko  
N. B. Snow  
P. J. Wade
- "Ecological effects of oil-dispersant mixtures in fresh water." 1979 Oil Spill Conf. Proc. American Petroleum Institute Publication No. 4308, pp. 565-571, 1979.
- I. Sekerka  
J. F. Lechner
- "Application of ion-selective electrodes as reference electrodes." Analytical Letters, Vol. 12, No. A12, pp. 1239-1248, 1979.
- J. P. Sherry  
S. R. Kuchma  
B. J. Dutka
- "The occurrence of *Candida albicans* in Lake Ontario bathing beaches." Can. J. Microbiol., Vol. 25, pp. 1036-1044, 1979.
- J. P. Sherry  
S. R. Kuchma  
B. J. Dutka
- "Confirmation tests for fresh water isolates of *Candida albicans*." Can. Res., Vol. 12, pp. 33-36, 1979.

#### ENVIRONMENTAL CONTAMINANTS DIVISION

- R. J. Allan  
J.D.H. Williams  
S. R. Joshi  
W. F. Warwick
- "Historical changes and relationship to internal loading of sediment phosphorus forms in hypertrophic Prairie Lakes." J. Environ. Qual., Vol. 9, pp. 199-206, 1980.
- R. M. Baxter
- "Environmental effects of dams and impoundments in Canada: Experience and prospects." Can. Bull. Fish. Aquat. Sci., Vol. 205, 34 pp. 1980.
- J. Carey  
B. G. Oliver
- "The photochemical treatment of wastewater by ultraviolet irradiation of semi-conductors." Presented at 15th Can. Symp. of Water Poll. Res. (Central Division), CCIW, Feb. 2 1980. Water Poll. Res. Can. (accepted).
- Y. K. Chau
- "Chemical and biological process of elements in the aquatic environment." Proc. NAS Workshop on Global Ecology, Washington, D.C., October 1979 (accepted).
- Y. K. Chau  
P.T.S. Wong
- "Techniques for separations and speciation of some metals and metalloids in environmental samples." Proc. Geo-Analysis-78 (accepted).

K. Chau T.S. Wong	"Biotransformation and toxicity of lead in the aquatic environment." Proc. Int. Experts Discussion on "Lead - Occurrence, Fate and Pollution in the Marine Environment", Rovinj, Yugoslavia, 1977 (in press, 1980).	D. Liu W.M.J. Strachan	"Comparison of rotary shakers and cyclone fermentors in the biodegradation of petroleum." Can. Res., Vol. 12, No. 4, pp. 26-27, 1980.
K. Chau T.S. Wong D. Goulden	"A sensitive technique for the analysis of tetraalkyllead." Proc. Int. Experts Discussion on "Lead - Occurrence, Fate and Pollution in the Marine Environment", Rovinj, Yugoslavia, 1977 (in press, 1980).	R. J. Maguire	"Pollutants in aquatic surface microlayers: a cautionary note." Internat. J. Environ. Anal. Chem., Vol. 7, p. 253, 1979.
K. Chau T.S. Wong A. Bengert Kramer	"Determination of tetraalkyllead compounds in water sediment and fish samples." Anal. Chem., Vol. 51, pp. 186-188, 1979.	R. J. Maguire E. J. Hale	"Fenitrothion sprayed on a pond: kinetics of its distributions and transformation in water and sediment." J. Agric. Food Chem., Vol. 28, p. 372, 1980.
K. Chau T.S. Wong Kramer A. Bengert	"Occurrence of tetraalkyllead compounds in the aquatic environment." Bull. Environ. Contam. Toxicol., Vol. 24, pp. 265-269, 1980.	R. J. Maguire E. J. Hale	"Distribution of fenitrothion sprayed on a pond and its transformation in water and sediment." In: Environmental Surveillance in New Brunswick; Effect of Spray Operations for Forest Protection, U. of New Brunswick, 1980.
W. Durham	"Great Lakes open waters and fish radionuclide concentrations." In: Appendix D, Great Lakes Water Quality 7th Annual Report, IJC, Windsor, Ontario, July 1979.	B. G. Oliver	"The effect of temperature and bromide concentration on the trihalomethane reaction of chlorine with aquatic humic material." Proc. 3rd Conf. on Water Chlorination, Environmental and Health Effects (accepted).
W. Durham R. Joshi	"Radionuclide concentration in two sewage treatment plants on western Lake Ontario." J. Radioanalytical Chem., Vol. 54, pp. 367-370, 1979.	B. G. Oliver J. Lawrence	"Haloforms in drinking water: a study of precursors and precursor removal." J. Amer. Water Works Assoc., Vol. 71, p. 161, 1979.
W. Durham R. Joshi	"Determination of $^{228}\text{Th}$ , $^{230}\text{Th}$ , $^{232}\text{Th}$ in environmental samples from uranium mining and milling operations." J. Radioanalytical Chem., Vol. 52, pp. 181-188, 1979.	B. G. Oliver S. A. Visser	"Chloroform production from the chlorination of aquatic humic material: the effect of molecular weight, environment and season." Water Res. (accepted).
W. Durham R. Joshi	"Investigation of Lake Ontario water quality near Port Granby Radioactive Waste Management Site." Water, Air, Soil Poll., Vol. 13, pp. 17-26, 1980.	B. G. Oliver E. G. Cosgrove D. H. Carey	"Effects of suspended sediments on the photolysis of organics in water." Environ. Sci. Technol., Vol. 13, p. 1075, 1979.
W. Durham R. Joshi J. Allan	"Radioactive dating of sediment cores from four contiguous lakes in Saskatchewan, Canada." Science of the Total Environment, Vol. 15, No. 1, pp. 65-71, 1980.	R. F. Platford	"Experimental methods: Isopiestic." In: Chapter 3 "Activity Coefficients in Electrolyte Solutions" (R. M. Pythowicz, ed.), CRC Press, Inc., pp. 65-79, 1979.
W. Durham R. Joshi	"Radionuclide removal in water filtration plants. Determination of radionuclide concentrations in Lake Ontario." Water Res. (accepted).	R. F. Platford	"Glyceryl trioleate-water partition coefficients for three simple organic compounds." Bull. Environ. Contam. Toxicol., Vol. 21, pp. 68-73, 1979.
L.E. Kaiser	"Organochlorine contaminants in the Great Lakes." Geoscience Can., Vol. 6, No. 1, pp. 16-19, 1979.	R. F. Platford	"Behaviour of $\text{AgClO}_4$ in water and benzene." J. Chem. & Eng. Data, Vol. 24, No. 1, pp. 70-71, 1979.
L.E. Kaiser	"Correlation and prediction of metal toxicity to aquatic biota." Can. J. Fish. Aquat. Sci., Vol. 37, pp. 211-218, 1979.	R. F. Platford	"Octanol-hexadecanol lenses on water." Can. J. Chem. Eng. (accepted).
L.E. Kaiser Valdmanis	"Volatile chloro- and chlorofluorocarbons in Lake Erie - 1977 and 1978." J. Great Lakes Res., Vol. 5, pp. 160-169, 1980.	B. Radziuk Y. Thomassen J. C. Van Loon Y. K. Chau	"Determination of alkylated compounds in air by gas chromatography and atomic absorption spectrometry." Anal. Chim. Acta., Vol. 105, pp. 255-262, 1979.
K. Kwasniewska D. Liu W.M.J. Strachan	"Bioassay of relative toxicity of some chlorophenols using sewage bacteria." In: Proc. 5th Annual Aquatic Toxicity Workshop (P.T.S. Wong, P. V. Hodson, A. J. Niimi, V. Cairns and U. Borgmann, Eds.), pp. 192-200, 1979.	B. Radziuk Y. Thomassen P. Butler J. C. Van Loon Y. K. Chau	"A comparison of several atomization systems used with atomic absorption and atomic fluorescence spectroscopic detectors for gas chromatography." Anal. Chim. Acta., Vol. 108, pp. 31-38, 1979.
D. Liu	"A novel selective enrichment technique for use in biodegradation studies." In: Proc. of Workshop "Microbial Degradation of Pollutants in Marine Environments", (A.W. Bourgin and P. R. Pritchard, Eds.) pp. 370-379, 1980.	B. F. Scott E. Nagy J. P. Sherry B. J. Dutka V. Glooschenko N. B. Snow	1979 Oil Spill Conference Proceedings, pp. 565-571, 1979.
D. Liu W.M.J. Strachan	"Characterization of microbial activity in sediment by resazurin reduction." Arch. Hydrobiol. Beih., Vol. 12, pp. 24-31, 1980.	W.M.J. Strachan G. E. Glass	"Organochlorine substances in Lake Superior." J. Great Lakes Res., Vol. 4, (3-4), pp. 389-397, 1978 (pub. 1980).
		W.M.J. Strachan H. Huneault	"Polychlorinated biphenyls and organochlorine pesticides in Great Lakes precipitation." J. Great Lakes Res., Vol. 5, pp. 61-68, 1979.



W.M.J. Strachan H. Huneault W. M. Schertzer F. C. Elder	"Organochlorines in precipitation in the Great Lakes region." In: Hydrocarbons and Halogenated Hydrocarbons in the Aquatic Environment (B. K. Afghan and D. Mackay, Eds.), Plenum Publishing Corp., New York, 1980.	R.J. Daley	"Direct epifluorescence enumeration of native aquatic bacteria: uses, limitations and comparative accuracy." In: Native Aquatic Bacteria, Enumeration, Activity and Ecology (J. W. Costerton and R. R. Colwell, Eds.), ASTM, 1979.
D.M.G. van den Berg P.T.S. Wong Y. K. Chau	"Measurement of complexing materials excreted from algae and their ability to ameliorate copper toxicity." J. Fish. Res. Bd. (Can.), Vol. 36, pp. 901-905, 1979.	E. C. Carmack	"Combined influence of inflow and lake temperature on spring circulation in a riverine lake." J. of Phys. Oceanogr., Vol. 9, No. 2, pp. 422-434, 1979.
P.T.S. Wong Y. K. Chau	"Methylation and toxicity of lead in the aquatic environment." Proc. Int. Conf. "Management Control of Heavy Metals in the Environment", London, pp. 131-134, 1979.	E. C. Carmack C.B.J. Gray C. H. Pharo R. J. Daley	"Importance of lake-river interaction on seasonal patterns in the general circulation of Kamloops Lake, British Columbia." Limnology and Oceanography, Vol. 24, No. 4, pp. 634-644, 1979.
P.T.S. Wong Y. K. Chau G. Burnison	"Cadmium toxicity to freshwater algae." Bull. Environ. Contam. Toxicol., Vol. 23, pp. 489-490, 1979.	P. F. Hamblin E. C. Carmack	"Mean field distributions of a dissolved substance on the vicinity of branches in a fjord system." In: Fjord Oceanogr., (H. Freeland, D. M. Farmer and C. D. Levinger, Eds.), Plenum Press, pp. 371-376, 1980.
HYDRAULICS DIVISION			
S. Beltaos	"Transverse mixing tests in natural streams." Can. J. Civil Eng., Vol. 6, No. 4, 575-91, 1979.	P. F. Hamblin E. C. Carmack	"A model of the mean field distribution of dissolved substance within the riverine lagoon of a fjord lake." Water Resources Res. (in press, 1980).
J. P. Coakley	"The geomorphology and origin of Point Pelee, southwestern Ontario: Discussion." Can. J. Earth Sci., Vol. 16, No. 3, part 1, pp. 617-618, 1979.	P. D. Killworth E. C. Carmack	"A filling-box model of river-dominated lakes." Limnology and Oceanography, Vol. 24, No. 2, pp. 201-217, 1979.
M. A. Donelan J. Hamilton W. H. Hui	"A statistical model for groupiness in wind waves." J. Geophys. Res., Vol. 84, No. C8, pp. 4875-4884, 1980.	C. H. Pharo E. C. Carmack	"Sedimentation processes in a short residence-time intermontane lake, Kamloops Lake, British Columbia." Sedimentology, Vol. 26, pp. 523-541, 1979.
P. Engel Y. L. Lau	"Friction factor for flow over duned beds." Proc. 4th Nat. Hydrotechnical Conf., Can. Soc. Civil Eng., Vancouver, 1979.	D. W. Quackenbush M. L. Bothwell P. A. Bisson	"Aluminum shadowing-direct projection photomicroscopy of diatom frustules." Can. J. Fish. Aquat. Sci. (in press, 1980).
P. Engel Y. L. Lau	"Computation of bed load using bathymetric data." J. Hydr. Division, ASCE (in press, 1980).	R. P. Reid C. H. Pharo W. C. Barnes	"Direct determination of apatite in lake sediments." Can. J. Fish. Aquat. Sci., Vol. 37, No. 4, pp. 640-646, 1980.
P. Engel K. Wiebe	"A hydrographic method for bed-load measurements." Proc. 4th Nat. Hydrotechnical Conf., Can. Soc. Civil Eng., Vancouver, 1979.	SCOR Working Group 58 (E. C. Carmack)	"The Arctic Ocean heat budget". U. of Bergen, Geophys. Inst. Report 52, 98 pp., 1979.
B. G. Krishnappan	"Mathematical modelling of flows in natural streams." Proc. 4th Nat. Hydrotechnical Conf., Can. Soc. Civil Eng., Vancouver, 1979.	R. C. Wiegand S. Pond	"Fluctuations of chlorophyll and related physical parameters in British Columbia coastal waters." J. Fish. Res. Bd. Can., Vol. 36, No. 2, pp. 113-121, 1979.
Y. L. Lau	"Laboratory study of cylindrical sedimentation traps." J. Fish. Res. Bd. Can., Vol. 36, No. 10, pp. 1288-91, 1979.	<u>Western and Northern Region</u>	
Y. L. Lau J. Moir	"Booms used for oil slick control." J. Environ. Eng. Division, ASCE, Vol. 105, No. 2, pp. 369-382, 1979.	R. J. Allan	"Sediment related fluvial transmission of contaminants: some advances by 1979." Environment Canada, Scientific Series, No. 107, 24 pp., 1979.
ENGINEERING AND COMPUTING SUPPORT DIVISION			
C. Y. Der	"A Water Velocity Sensor for the Measurement of Three-Dimensional Turbulence." Proc. of OCEANS'79, IEEE Publication No. 79CH1478-7 OEC, pp. 312-319, 1979.	R. J. Allan	"Heavy metals in bottom sediments of Great Slave Lake (Canada) a reconnaissance." Environmental Geology, Vol. 3, pp. 49-58, 1979.
C. Y. Der	"Flow response tests of a prototype profiling sonde configuration." Exposure, Vol. 7, No. 6, pp. 1-7, 1980.	R. J. Allan	"The inadequacy of existing chlorophyll-phosphorus concentration correlations for assessing remedial measures for hypertrophic lake." Environmental Pollution, Series, Part 1, Vol. 1, pp. 41-55, 1980.
REGIONAL REPORTS			
<u>Pacific &amp; Yukon Region</u>			
M. L. Bothwell J. G. Stockner	"Influence of secondarily heated kraft mill effluent on the accumulation rate of attached algae in experimental continuous flow troughs." Can. J. Fish. Aquat. Sci., Vol. 37, No. 2, pp. 248-254, 1980.	R. J. Allan M. Roy	"Lake water nutrient chemistry and chlorophyll-a in Pasqua, Echo, Mission, Katopwa, Crooked and Round Lakes on the Qu'Appelle River, Saskatchewan." Environment Canada, Scientific Series No. 112, 66 pp., 1980.
		R. J. Allan J.D.H. Williams S. R. Joshi W. F. Warwick	"Historical changes and relationship to internal loading of phosphorus forms in hypertrophic prairie lakes." J. Environmental Quality, Vol. 9, pp. 199-206, 1980.



- A. Jackson "Relationships between the properties of heavy metals and their biogeochemical behaviour in lakes and river-lake systems." Proc. Internat. Conf. on Heavy Metals in the Environment, London, 1969. Pub. CEP Consultants, Edinburgh, Scotland, pp. 457, 560, 1979.
- A. Jackson "Sources of heavy metal contamination in a river-lake system." Environmental Pollution, Vol. 18, pp. 131-138, 1979.
- A. Jackson  
E. Hecky "Depression of primary productivity by humic matter in lake and reservoir waters of the boreal forest zone". Can. J. Fish. Aquat. Sci. (in press, 1980).
- A. Jackson  
Kipphut  
H. Hesselein  
W. Schindler "Experimental study of trace metal chemistry in soft-water lakes at different pH levels." Can. J. Fish. Aquat. Sci., Vol. 37, pp. 387-402, 1980.
- A. Jackson  
N. Woychuk "A preliminary report on the geochemistry of mercury in polluted sediments of Thunder Creek, Saskatchewan." NWRI-WNR, PR-79-3, 1979.
- A. Jackson  
N. Woychuk "The geochemistry and distribution of mercury in the Wabigoon River system." In Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures: A Progress Report for 1979-1980. (T. A. Jackson, Ed.) 28 pp., 1980.
- C. Kenney "Lake surface fluctuations and the mass flow through the Narrows of Lake Winnipeg." J. Geophys. Res., Vol. 84, pp. 1225-1235, 1979.
- G. Laksham "A study of phosphate contribution to the Fishing Lakes from the shoreline cottages in the Qu'Appelle Basin." NWRI-WNR, PR-79-2, 1979.
- W. R. Warwick "Palaeolimnology of Pasqua Lake: a preliminary report on benthic fauna responses to the sediment-water environment and long core collection during February-March, 1969." NWRI-WNR, PR-79-4, 113 pp., 1979.
- W. F. Warwick "Pasqua Lake southeastern Saskatchewan: a preliminary assessment of trophic status and contamination based on the Chironomidae (Diptera)." in: Chironomidae Ecology, Systematics, Cytology and Physiology (D. A. Murray, Ed.), Pub. Pergamon Press, pp. 255-267, 1980.
- W. F. Warwick "Chironomidae (Diptera) responses to 2,800 years of cultural influence: a palaeolimnological study with special reference to sedimentation, eutrophication and contamination processes." Can. Entomologist (in press, 1980).
- W. F. Warwick "Man and the Bay of Quinte, Lake Ontario: 2,800 years of cultural influence, with special reference to the Chironomidae (Diptera), sedimentation and eutrophication." Bull. of the Can. J. Fish. Aquat. Sci. (in press, 1980).



## STAFF LIST





## DIRECTOR'S OFFICE

Director - Dr. G. Keith Rodgers  
Secretary - Mrs. C. Leacock  
Receptionist - Mrs. K. Finch

Public Liaison Officer - Vacant  
Clerk - Mrs. I. Powell

Senior Scientist - Dr. R. A. Vollenweider  
Secretary - Mrs. S. Horne

Health Organization/CC/SGWQ - Dr. S. Barabas  
Secretary - Mrs. N. Clegg

Researcher - Dr. P. G. Sly

## AQUATIC ECOLOGY DIVISION

Chief - Dr. J. M. Barica  
Secretary - Ms. J. Major  
Administrative Officer - Mr. F. Boyd

### Nutrient Dynamics Section

Head - Dr. B. K. Burnison - "dissolved" organic carbon and phosphorus

Researchers:

A. Abbott (term) - phosphorus kinetics studies and data analysis  
B. G. Brownlee - nitrogen metabolism, forms of dissolved organic nitrogen  
N. M. Burns - particle settling, Lake Erie  
M. N. Charlton - biomass & productivity response of nutrients, oxygen depletion  
D. R. S. Lean - nutrients and algae growth  
G. G. Leppard - colloidal fibrils, refractory organics  
B. Manning - phosphorus and iron in sediments  
T. P. Murphy - algal iron chelators, lake restoration techniques  
D. S. Painter - aquatic macrophytes, control techniques  
F. Rosa - oxygen depletion, particle settling  
D. B. Shindler - microbial ecology

Technicians: Mr. A. Bobrowski, Mr. W. Booth, Mr. H. F. H. Dobson, Mrs. K. Edmondson, Mrs. D. J. Nuttley, Ms. J. Wood (term)

### Wetlands Ecology Section

Head - Dr. W. A. Glooschenko - wetlands ecology, biogeochemistry

Researchers:

R. A. Bourbonniere - organic geochemistry  
R. K. McMillan - underwater acoustics, geophysics  
J. O. Nriagu - low temperature geochemistry  
R. G. Sandilands - environmental geology, underwater photography, computer applications in geology  
H. K. T. Wong - sediment/water geochemistry, geochronology

Technicians: Mr. N. Arafat, Mr. R. Coker, Mrs. N. S. Harper, Mrs. T. Mayer

### Paleoenvironmental Section

Head - Dr. L. D. Delorme - paleoenvironmental research

Researchers:

S. R. Esterby - applied statistics  
L. L. Kalas - paleoenvironmental research

## AQUATIC PHYSICS AND SYSTEMS DIVISION

Chief - Mr. F. C. Elder  
Secretary - Mrs. S. M. Tapping

### Basin Investigation and Modelling Section

Administrative Officer - Mr. A. W. Mayes

Scientific Staff:

Head - Dr. C. R. Murthy - physical limnology  
Mr. F. M. Boyce - physical limnology  
Mr. J. A. Bull - physical limnology  
Mr. F. Chiocchio - physical limnology  
Dr. A. H. El-Shaarawi - statistical modelling  
Mr. A. S. Fraser - water quality modelling  
Dr. E. Halfon - toxic substance modelling  
Dr. P. F. Hamblin - physical limnology  
Dr. D. C. L. Lam - water quality modelling  
Mr. K. C. Miners - coastal zone research  
Mr. W. M. Schertzer - water quality modelling  
Dr. T. J. Simons - hydrodynamic modelling  
Mr. R. O. W. Kuehnle - physical limnology

Technical Staff:

Mr. M. Kerman - physical limnology  
Mr. D. G. Robertson - physical limnology  
Mrs. N. Snelling - secretary

### Environmental Spectro-Optics Section

Head - Dr. R. P. Bukata - lake optics and satellite studies  
Mr. J. H. Jerome - lake optics and remote sensing  
Mr. J. E. Bruton - lake optics and remote sensing  
Mr. A. G. Bobba - hydrogeology and remote sensing

### Data Management Section

Professional:

Head - Mr. J. Rogalsky - data management services  
Mr. S. Beal - minicomputer applications  
Mr. R. Duffield - data base administration  
Mrs. H. Comba - software development  
Supervisor  
Mr. B. Hanson - software development  
Ms. J. Dowell - software development  
Mrs. G. Ozolins - software development  
Mrs. K. Miles - software development  
Mrs. J. Hodson - software development  
Mr. A. Zingaro - software development  
Mr. B. Ventresca - software development

Technical:

Mr. R. Gottinger - special projects development  
Mr. W. Nagel - data archiving  
Supervisor  
Mr. J. Byron - data archiving  
Mrs. J. McAvella - data archiving  
Mrs. D. Crabtree - word processing

### Long-Range Transport of Air Pollutants Task

Head - Dr. E. B. Bennett - aquatic effects, LRTAP  
Dr. M. E. Thompson - aquatic effects, LRTAP  
Mr. R. G. Semkin - aquatic effects, LRTAP

## ANALYTICAL METHODS DIVISION

Chief - Dr. J. Lawrence  
Secretary - Mrs. J. Burford  
Administrative Officer - Mr. A. W. Mayes

### Analytical Chemistry Research Section

Head - Dr. B. K. Afghan - high pressure liquid chromatography, polarography, molecular fluorescence spectrometry

#### Researchers:

Dr. P. D. Goulden - automation & atomic spectroscopy  
Dr. I. Sekerka - electroanalytical  
Dr. F. I. Onuska - gas chromatography & GC/MS

Technicians: Mr. J. R. Ryan, Mr. R. J. Wilkinson, Mr. J. R. Lechner, Mr. D. H. Anthony, Mr. M. E. Comba, Mr. R. Thomson

### Microbiology Laboratories Section

Head - Mr. B. J. Dutka - microbiological methods, toxicity screening

#### Researchers:

Dr. S. S. Rao - microbiology

Technicians: Mr. A. A. Jurovic, Mr. K. K. Kwan, Mr. S. R. Kuchma, Mr. R. McInnis, Ms. A. Jova, Ms. K. Walsh

### Quality Assurance and Methods Section

Head - Mr. A. S. Y. Chau - quality control design, standard reference materials, methods adaptation and development

#### Researchers:

Mr. H. Agemian - method development (org. & inorg.), some quality control studies  
Mr. K. I. Aspila - IJC Q.C. Program and National Q.C.  
Mr. L. J. Babjak - organic method development  
Mr. V. F. Cheam - specification generation, interregional Q.C., preservation studies  
Mr. H. B. Lee - National and IJC Q.C. (organics) standard reference materials (organics), sample storage conditions, methods evaluation

### Electron Microscope Facility

Mr. T. Bistricki - electron microscopy

### Clean & High Hazard Laboratory

Dr. B. K. Afghan

### ENVIRONMENTAL CONTAMINANTS DIVISION

Chief - Dr. R. J. Allan  
Secretary - Mrs. E. M. Kerr  
Administrative Officer - Mr. F. Boyd

### Environmental Radioactivity Section

Head - Dr. R. W. Durham - impact of nuclear power development

#### Researchers:

Mr. G. H. Jamro - radiological surveillance  
Dr. S. R. Joshi - pathways of radionuclides

Technologists: Mr. J. FitzGerald

### Toxic Substances Section

Head - Dr. W. M. J. Strachan - organic contaminants in aquatic systems, especially rain

#### Researchers:

Dr. Y. K. Chau - chemical and biological process of elements in the aquatic environment  
Dr. M. E. Fox - persistent organic contaminants aquatic ecosystems  
Dr. K. L. E. Kaiser - structure-activity correlations of contaminants  
Mrs. K. Kwasniewska - degradation of organic contaminants and toxicity to microorganisms  
Dr. D. L. Liu - persistence of toxic organic compounds  
Dr. K. R. Lum - chemical forms of trace metals  
Dr. R. J. Maguire - geochemistry of particulate matter  
Mrs. A. Mudroch - aquatic fate of organometallic compounds  
Dr. E. Nagy - chemical forms of trace metals suspended solids and bottom sediments  
Dr. B. F. Scott - fate and effects of contaminants (2,4-D)  
environmental fate and effect of contaminants

Technologists: Mr. G. A. Bengert, Mrs. E. J. Hale, Mr. J. H. Hale, Mr. H. Huneault, Mrs. K. Thomson, Mrs. Valdmanis

### Water Chemistry Section

Head - Dr. J. Lawrence - impact of natural organic chemicals

#### Researchers:

Dr. R. M. Baxter - photochemistry of aquatic humic materials  
Dr. J. H. Carey - photodegradation of environmental contaminants  
Dr. B. G. Oliver - sources of aquatic organic contaminants, chlorination by-products, spectroscopic techniques  
Dr. R. F. Platford - physical chemistry of surface films

Technologists: Mrs. K. Bohen, Mr. R. Tkacz

### HYDRAULICS DIVISION

Chief - Dr. T. M. Dick  
Secretary - Mrs. A. Mueller

### Administrative Unit

Stenographic, Clerical and General Services:

Miss D. Jacobs  
Mrs. E. Jones

### Environmental Hydraulics Section

Head - Dr. Y. L. Lau - river dynamics

#### Researchers:

Dr. S. Beltaos - river ice  
Mr. P. Engel - river engineer  
Dr. B. G. Krishnappan - river dynamics  
Mr. J. Marsalek - urban hydrology  
Mr. H. Ng - urban hydrology  
Dr. G. Tsang - ice studies

### Shore Processes Section

Head - Dr. M. G. Skafel - coastal engineering

#### Researchers:

Mr. C. T. Bishop - coastal engineering  
Mr. J. P. Coakley - coastal sedimentology  
Dr. M. A. Donelan - air-water interaction  
Dr. N. A. Rukavina - coastal sedimentology  
Mr. A. J. Zeman - geotechnical studies



## Technical Services Section

Head - Mr. C. DeZeeuw

### Laboratory Services:

D. Fekyt  
E. Nash  
G. Voros  
W. Welmers

### Environmental Hydraulics Support Unit:

J. Dalton  
F. Doede  
F. Dunnett  
G. Ferraro - presently with University of Guelph  
J. Heidt - Unit Head  
K. Hill  
D. Jones  
W. Moody  
S. R. Purves (formerly Miss R. Toni)  
K. Salisbury

### Core Processes Support Unit:

D. Beesley  
G. A. Duncan - Unit Head  
G. G. LaHaie  
S. G. P. McInnis - presently with Water Quality Branch, IWD  
T. Nudds

### International Calibration Service:

C. Bil  
S. B. Near

## ENGINEERING & COMPUTING SUPPORT DIVISION

Chief - Mr. A. S. Atkinson  
Secretary - Ms. M. J. Brechin  
Administrative Officer - Mr. S. C. Smith

## Engineering Services Section

Head - Mr. J. S. Ford  
Secretaries - Ms. M. J. Brechin  
Mrs. I. Green

### Electronic Engineering Unit:

Head - Mr. J. S. Ford  
S. C. Y. Der - environmental sensor design  
J. R. Desrosiers - electro-optical design  
E. Harrison - digital electronics design  
A. S. Watson - special assignments  
B. F. White - electro-acoustic design

Technologists: Mr. G. Dolanjski, Mr. M. Pedrosa

### Electronic Maintenance Unit:

Head - Mr. J. Valdmanis

Technologists: Mr. J. Diaz, Mr. A. Fletcher, Mr. K. Mollon, Mr. E. Smith, Mr. A. Tyler, Mr. J. Thomson

### Mechanical Engineering Unit:

Head - Mr. A. E. Pashley  
F. Roy - electro-mechanical design

Technologists: Mr. R. Boucher, Mr. P. Carney, Mr. H. Savile

### Machine Shop:

Supervisor - Mr. D. Whyte

Draftsmen: Mr. J. Bidinost, Mr. R. Chumley, Mr. K. Kalter

## Drafting and Illustrating Office:

Supervisor - Mr. W. D. Finn

Draftsmen: Mr. M. Donnelly, Mr. P. McColl, Mr. J. Van Nynatten

## Computer Services Section

Head - Mr. H. C. Pulley

Ms. M. Kinder - operations supervisor  
Mr. B. Malseed - computer console operator  
Ms. U. Hamilton - computer console operator  
Ms. M. Thomson - computer console operator  
Ms. J. Foley - keypunch & peripheral operator

## TECHNICAL OPERATIONS DIVISION

Head - Mr. H. B. Macdonald  
Secretary - Mrs. S. R. Mitchell

### Shore Unit

Mr. W. B. Taylor - senior operations officer  
Mr. L. E. Benner - GLBL, Sault Ste. Marie  
Mr. T. J. Carew - HD, Burlington and Pt. Burwell  
Mr. B. L. Killins - instruments, data  
Mr. G. J. Koteles - GLBL, Dorset and Quinte  
Mr. M. R. Thompson - HD, Burlington and Pt. Burwell  
Mr. E. H. Walker - Canadian Wildlife Service  
Mr. B. G. Gillies - HD, Burlington and Pt. Burwell

### Ship Unit

#### Surveillance:

Mr. M. R. Mawhinney - operations officer  
Mr. J. R. Brown  
Mr. G. D. Bruce  
Mr. P. R. Youakim

#### CSS LIMNOS:

Mr. P. M. Healey - operations officer  
Mr. S. B. Smith  
Mr. J. E. Tozer  
Mr. R. J. Hess  
Mr. T. F. MacLennan

#### CSS ADVENT:

Mr. B. H. Moore

#### MV LAC ERIE:

Mr. F. H. Don

### Special Projects Unit

Mr. R. G. Chapil - special projects officer  
Mr. H. K. Nicholson

### Dive Unit

Mr. J. T. Roe - senior diving officer  
Mr. F. J. deVree - diver

### Rigging Unit

Mr. L. J. Lomas - foreman  
Mr. H. E. Greencorn - rigger  
Mr. G. M. Perigo - rigger  
Mr. W. D. Hunt - field storesman

## STAFF SERVICES DIVISION

Acting Chief - Mr. A. S. Atkinson  
 Secretary - Mrs. I. Powell  
 Administrative Services - Mrs. B. Titley

### Financial Services

Acting Head - Mr. A. Mitchell

Support Staff: Mr. E. Mulvaney, Mr. D. Jefferson, Mrs. Y. Hutton,  
 Mrs. M. Eadie, Mr. R. Haswell, Ms. E. A. King  
 (term)

### Central Registry

Supervisor - Mrs. E. Rae

Support Staff: Mrs. M. T. Solvason, Mrs. J. A. Sims

### Materiel Management

Head - Mr. C. F. Hicks

Support Staff: Mr. J. P. Mellon, Mr. D. M. Niles, Mr. T. A.  
 Williams, Mr. S. Hicks

### Building and Property Services

Head - Mr. D. F. Stewart  
 Safety Officer - Mr. R. J. Gray  
 Nurse - Miss C. Shulver

Support Staff: Mr. J. C. Stewart, Mr. D. J. Smith, Mr. C. K. Platt,  
 Mr. K. Taylor, Mr. J. R. Riddell, Mr. F. Adams, Mr.  
 A. K. Allaby, Mr. M. Connors, Mr. D. W. Clewley,  
 Mr. J. P. Denomme, Mr. W. A. Johnson, Mr. T.  
 Comiskey

## PACIFIC AND YUKON REGION

Chief - Dr. R. J. Daley

### Researchers:

Dr. M. L. Bothwell	-	benthic ecology
Dr. E. C. Carmack	-	physical limnology
Mr. C.B.J. Gray	-	chemical limnology
Mr. S. Jasper	-	biological limnology
Dr. C. H. Pharo	-	sedimentology and geochemistry
Mr. R. C. Wiegand	-	physical limnology

Technicians: Mr. V. Champerlain, Mr. S. Flynn, Mr. R. Kirkland,  
 Mr. E. Marles, Mr. K. Suzuki, and Mr. D. Turner

## WESTERN AND NORTHERN REGION

Chief - Dr. R. J. Allan

### Professional:

Dr. R. J. Allan	-	nutrient/productivity relations, met
		pollution of aquatic systems
Dr. T. A. Jackson	-	metal biogeochemistry, nutrient ge
		chemistry
Dr. B. C. Kenney	-	wind generated mixing processe
		physical limnology
Dr. W. F. Warwick	-	palaeolimnology, benthic studies

### Technical:

Mr. J. C. Mollison	-	physical limnology technologist
Mr. M.A.P. Roy	-	field limnology technologist/assistant
		chief
Mr. J. P. Tisdale	-	geochemical technologist
Mr. R. N. Woychuk	-	biogeochemical technologist





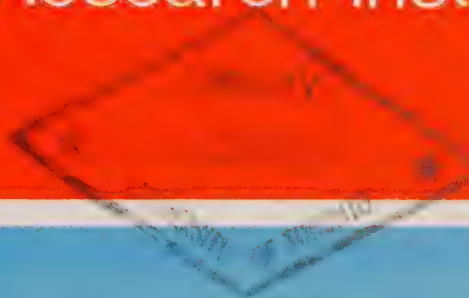




ENVIRONMENT  
CANADA

CAI  
MT64  
- C55

# National Water Research Institute



## 1981-1982 REPORT

Cover photograph by D. Fekyt.

On peut aussi obtenir cette publication en français.



**NATIONAL WATER RESEARCH INSTITUTE**

**Report 1981/82**

National Water Research Institute  
Inland Waters Directorate  
Burlington, Ontario, Canada

Address:  
Post Office Box 5050  
Burlington, Ontario, Canada  
L7R 4A6

## NATIONAL WATER RESEARCH INSTITUTE

### N O T E

NOTICE is hereby given that mention of any product or material in this publication is not to be taken as indicating that the National Water Research Institute in any way approves, recommends or endorses any such product or material. No mention shall be made of the National Water Research Institute or of this publication in any advertising, sales promotion, reports or other written or graphic material which would indicate or imply that the National Water Research Institute approves, recommends or endorses any product or material mentioned herein, or which has as its purpose an intent to use the name of the National Water Research Institute or this publication as a means, directly or indirectly, of causing, aiding or enhancing the sale or use of any such advertised product or material.



National Water Research Institute  
Inland Waters Directorate  
867 Lakeshore Road  
P.O. Box 5050  
BURLINGTON, Ontario, Canada  
L7R 4A6

This is the second (the first was for the years 1979-80) comprehensive summary of the scientific programs of the National Water Research Institute (NWRI). These programs address a wide variety of problems associated with the protection, enhancement, development and use of Canada's water resources.

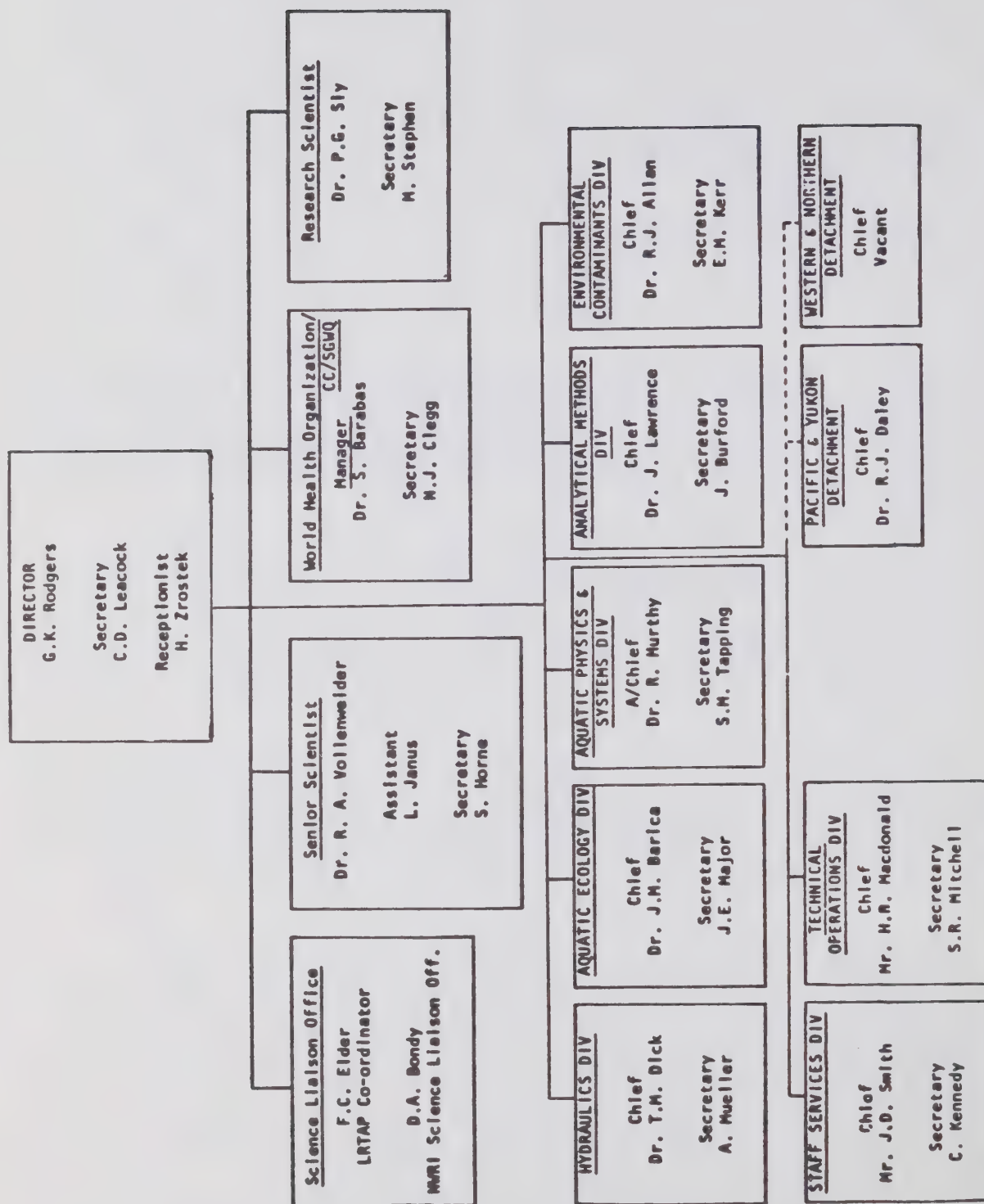
In this edition the staff describe the results of the past two years work, and outline the on-going activities in the fields of environmental contaminants, aquatic physics, aquatic systems, analytical methodology, instrumentation, hydraulics and aquatic ecology. In addition, all the associated scientific services including engineering, developmental work, the technical operations program and supporting services are described.

Here we present the results of a dedicated effort to advance, apply and disseminate knowledge of considerable scientific merit and practical import that will be of interest to our clientele in federal and provincial agencies; in federal-provincial and Canada-U.S. boards; in citizen groups, academic institutions and industry; as well as the public at large.

G.K. Rodgers  
Director



# NATIONAL WATER RESEARCH INSTITUTE



## TABLE OF CONTENTS

LETTER OF TRANSMITTAL	Page i
ORGANIZATION CHART	ii
HIGHLIGHTS	3
NATIONAL WATER RESEARCH INSTITUTE	7
Introduction	
Senior Scientist	
WHO Collaborating Centre on Surface and Ground Water Quality	
Habitat Studies	
ENVIRONMENTAL CONTAMINANTS DIVISION	15
Organics-Properties Section	
Organics-Pathways Section	
Inorganics Section	
Radionuclides Section	
ANALYTICAL METHODS DIVISION	49
Analytical Chemistry Research Section	
Quality Assurance and Methods Section	
Microbiology Laboratories Section	
Computer Services Section	
AQUATIC PHYSICS AND SYSTEMS DIVISION	65
Basin Investigation and Modelling Section	
Spectro-Optics and Remote-Sensing Section	
Data Management Section	
Long-Range Transport of Airborne Pollutants Task	
AQUATIC ECOLOGY DIVISION	91
Nutrient Pathways Section	
The Great Lakes Section	
Ecological Impact Section	
HYDRAULICS DIVISION	105
Engineering Services Section	
Environmental Hydraulics Section	
Shore Processes Section	
Technical Services Section	

TECHNICAL OPERATIONS DIVISION	131
<ul style="list-style-type: none"> <li>CSS LIMNOS - Lake Ontario</li> <li>                  - Lake Erie</li> <li>CSS BAYFIELD</li> <li>GLFRB Georgian Bay Benthic Survey</li> <li>Acid Rain</li> <li>Canadian Wildlife Service</li> <li>Port Burwell Erosion Studies</li> <li>Sediment Drift Studies</li> <li>Solids and Surf Zone Currents</li> <li>Other Projects</li> <li>Underwater Operations Unit</li> <li>Limnological Instrumentation Section</li> <li>Rigging Unit</li> </ul>	
STAFF SERVICES DIVISION	141
REGIONAL REPORTS	147
<ul style="list-style-type: none"> <li>Western &amp; Northern Region</li> <li>Pacific &amp; Yukon Region</li> </ul>	
PUBLICATIONS	169
<ul style="list-style-type: none"> <li>Senior Scientist</li> <li>Habitat Studies (ECS-552)</li> <li>Environmental Contaminants Division</li> <li>Analytical Methods Division</li> <li>Aquatic Physics &amp; Systems Division</li> <li>Aquatic Ecology Division</li> <li>Hydraulics Division</li> <li>Technical Operations Division</li> <li>Western &amp; Northern Region</li> <li>Pacific &amp; Yukon Region</li> </ul>	
STAFF LIST	203
COMMITTEE MEMBERSHIP	217



## HIGHLIGHTS

The following represent some of the highlights of the 1981/82 activities described in more detail in the body of this report.

A major study of man's impact on Lake Erie concluded that the lake can be restored and maintained in an acceptable state with moderate expenditures and careful decisions in the future.

The phosphorus deficiency index showed that the Central Basin of Lake Erie becomes deficient faster than the Eastern Basin and by early June is nearing the extreme range. The phosphorus limitation in the Central Basin is relaxed in late August and the system ceases to be phosphorus-limited during September. In contrast, the Eastern Basin takes longer to become phosphorus-limited but remains so during September and even into October. Generally, phosphorus has declined in the lower lakes but nitrate is now increasing rapidly.

The presence of particles was studied with light transmission profiles of the water column in Lake Ontario. The August and September profiles showed three distinct layers; an upper section with reduced transmission due to increased productivity in the warmer epilimnion, a relatively clear mid-water column, and then a lower section with transmission decreasing towards the lake bottom. This lower section or nepheloid (cloudy) layer was detected lake-wide, at all stations with a water depth greater than 60 metres.

The first year of a demonstration experiment on long-term control of Eurasian watermilfoil by mechanical harvesting was completed. Chemical control of Eurasian watermilfoil using 2,4-D was shown to have minimum environmental impact. Aquatic macrophytes growing in acid lakes were observed to release nickel, zinc and copper rapidly into the water column. The release rates far exceeded atmospheric deposition.

The long-term persistence of three herbicide residues was examined in the sediments of Wood and Kalamalka Lakes, B.C. In both lakes, 2,4-D was the longest lived. Undetectable levels were reached in 120 days, after treatment, in Wood Lake and in about 180 days in Kalamalka Lake. 2,4-D BEE and 2,4-DP dropped below detection after 54-77 days except in Kalamalka Lake where the ester persisted longer, about 72-125 days.

A model was developed to describe the fate of fenitrothion aerially sprayed in New Brunswick to kill the spruce budworm. The model predicted that it would take from 54 to 66 hours for the fenitrothion to disappear and for the environment to be safe. Another model for Mirex in Lake Ontario predicted that this persistent pesticide is sometimes bioavailable and might remain in the bottom sediments for the foreseeable future.

Lake Ontario water, sediments and fish contained much higher chlorobenzene concentrations (10 to 20 times) than samples from Lakes Superior, Huron, or Erie. The major sources of these chlorobenzenes were found to be the Niagara River where chemical plant effluents and leachates from waste disposal sites are concentrated.

Studies have shown that bacterial culture is capable of degrading chlorinated biphenyls. The tentative conclusion is that the products of this bacterial degradation undergo photochemical and spontaneous reactions leading to their further degradation and polymerization.

Readily exchangeable metal forms were found to arise from inputs of salt-laden water during the spring run-off period as a consequence of road-salting during winter. The metal ions in this fraction are then available to the biotic community at a very sensitive stage in the life cycle of many organisms.

Methyl mercury levels in the Wabigoon River-English River system (northwestern Ontario) depend more on environmental variables such as temperature, pH, nutrient supply, microbial activity, and the abundance and nature of mercury-binding sediment components than on total mercury levels. With increasing distance downstream from the source of pollution (Dryden, Ontario), total mercury levels in sediments decrease sharply, but the mercury becomes more available and readily methylated.

The rates of selenium and arsenic deposition in some of the lakes in the Sudbury area are among the highest recorded anywhere in Canada and show historical changes in the intensity of input of the two elements. The current depositional rate for potential pollutant metals in soft water lakes in the Algonquin area of Ontario exceed the contribution from national sources by 100 to 200%.

Data gathered in the Turkey Lakes watersheds, in the Algoma district of Ontario, suggest that sulphuric acid is the more important weathering agent (compared to carbonic acid) in the upper reaches of the watershed where soil-precipitation interactions are minimized.

A study of the effects of acid water on leaching of metals from domestic water supplies revealed that decreasing pH increased the rates of leaching of lead, copper and zinc. A survey of 105 homes in Toronto showed that the first drawn water always contained more metals than that after a 5-minute running.

Evaluation of surface water chemistry data from Atlantic Canada led to the discovery of a natural exchange of marine sodium for freshwater calcium in the basins of various coastal rivers. The data were also used to develop a model that relates the excess  $\text{SO}_4$  in

run-off to the median pH of the river. Ontario's Algonquin lakes, which had been showing small but consistent increases in  $\text{SO}_4$  concentrations from 1975 to 1979, in 1980 displayed lower, and in 1981 sharply lower  $\text{SO}_4$  concentrations. In response to the lower  $\text{SO}_4$  concentrations, the pH increased. Precipitation sampling network data show similar, nation-wide lower loads in 1980 than in 1979. The trend reversal might be due to either meteorological factors or to reduced emissions of  $\text{SO}_2$ .

In data management, the major acid rain data base system and analysis facilities were expanded to meet added study requirements for Eastern Canada. In addition, interactive graphics facilities in support of research were developed including implementation of new digitization hardware and software.

Analysis of water and sediment samples collected from two acid-stressed lakes, one near Batchawana, Ontario, and the other near Halifax, Nova Scotia, implied that normal biodegradation and biotransformation processes are effectively suppressed at low pHs, and normal turnover activities and food chains are interrupted, thus accelerating the degradation of the lakes.

Radionuclides measured in Great Lakes water and fish were apparently all introduced by fallout from nuclear-weapons testing since no evidence was found of radionuclides specifically related to industrial nuclear activities.

Methods for the determination of trace metals in environmental samples using atomic emission spectroscopy with inductively coupled argon plasma (ICAP) excitation have been developed to the point where routine determination of 12 trace metals can be carried out at levels below  $\mu\text{g/L}^{-1}$ .

Studies of persistent toxic substances in the Niagara River indicated the presence of more than 197 organic micropollutants, detected by gas chromatography/mass spectrometry (GC/MS). A high resolution GC/High resolution MS was also used on a number of fish extracts from the Great Lakes Basins to confirm the presence of 2,3,7,8-Tetrachlorodibenzo-p-dioxin.

The construction and installation of a Goodyear-type floating tire breakwater in Burlington, Ontario, believed to be the world's largest, was observed and documented in a film and in a report. Design information for the breakwater was drawn from the design manual for floating tire breakwaters prepared by NWRI.

An investigation of the distributions of velocity and suspended sediment concentration in river flows with ice cover was made. The results lend support to the conventional technique of discharge measurement under ice and provide a guide for the estimation of suspended sediment load.



A major study on Canadian lakes revealed that OECD eutrophication relationships are valid over a large spectrum of different lake types but that the application in particular cases must be done with caution.

By the end of 1981, close to 300 monitoring stations on major rivers, lakes and aquifers in 40 countries around the world were established and reporting GEMS water data to the WHO Centre at NWRI. Two 2-week training courses in GEMS/WATER operations were held in Africa in 1981: the first one in Dakar, Senegal, for the benefit of the French-speaking countries of Africa; the second one in Nairobi, Kenya, for the English-speaking countries of Africa. During the year, a chapter on Sediment Analysis was added to the GEMS/WATER Operational Guide.

There appear to be problems in achieving successful reproduction and re-use of historic Great Lakes fish-spawning sites. Variations in the fall, winter and spring climatic regimes indicate that year-to-year changes are great enough at many potential spawning sites to impair the reliability of hatch and fry development.

## INTRODUCTION

The National Water Research Institute (NWRI) of the Inland Waters Directorate is an environmental research organization at the Canada Centre for Inland Waters (CCIW) in Burlington, Ontario, and is part of the Department of the Environment.

Programs are implemented by five research divisions - Aquatic Ecology, Aquatic Physics and Systems, Analytical Methods, Environmental Contaminants, and Hydraulics.

While NWRI is still experiencing the substantial effects of government restraint on resource allocations aggravated by inflation, the staff have been successful in developing leadership for studies that have drawn new subject-specific resources to the Institute in the areas of contaminants, contracting into the Hydraulics laboratory, long-range transport of airborne pollutants (including acid rain), aquatic impact of nuclear power development, and investigations for the Great Lakes Water Quality Agreement of 1978.

The National Water Research Institute carries out a program of research and development designed to meet the objective of providing the necessary information and understanding of water systems for water management problems or opportunities in Canada. Building on this program of research and development, it seeks to advance, apply and disseminate scientific and engineering knowledge in the field represented by the research programs. The work includes field and laboratory research on problems of natural or man-modified aquatic regimes and contracted research. Problems investigated are of national scope or are related to specific geographical sites referred by other agencies within or from outside the Department of the Environment. Also part of the total program are provision of advice or information through publications, services on a consultative basis to other government agencies, service on scientific and technical committees of the government or government-supported institutions such as the International Joint Commission, and the provision of scientific services such as calibrations, analytical services, instrument testing, methodology documentation or interlaboratory quality control services.

Although the headquarters is at CCIW, detachments of NWRI are located in Winnipeg and Vancouver. Also, one senior staff member has been assigned to the Glenora Research Station of the Ontario Ministry of Natural Resources and a small unit working on the Long Range Transport of Airborne Pollutants is based at the GLFRC in Sault Ste. Marie, Ontario. There are many other temporary field sites occupied across Canada as the need arises.

## SENIOR SCIENTIST

Dr. R.A. Vollenweider, the Senior Scientist of the National Water Research Institute, has continued to be involved in international activities. In cooperation with OECD and EPA he has been involved in organizing a Conference held in Portland, Maine, September, 1980, on "Restoration of Lakes and Inland Waters" at which the main results of the OECD International Cooperative Program on Eutrophication, a multi-year study of which he was Chairman, were disseminated and reviewed. He was also invited by the organizers of the International Association of Water Supply to introduce the "Specialized Conference on Eutrophication" sponsored by the Association in October, 1981, in Vienna, Austria, and to summarize its results in a closing session. In accordance with OECD, he approached UNESCO to seek continuation of the OECD Program involving also non-OECD countries, and as a result, a workshop was held at IIASA, Laxenburg, Austria, October, 1981, at which the production of a practical manual on eutrophication control was chosen as an initial UNESCO activity in this field. Dr. Vollenweider acts as Senior Advisor to UNESCO in this new program. In addition to this, he has been approached by WHO to assist in developing guidelines for eutrophication control in drinking water reservoirs located in warm-climate countries, and to advise on the Bou Regreg case study in Morocco.

In cooperation with Dr. S. Barabas, two special volumes "Eutrophication - A Global Problem" have been published in the WHO-Water Quality Bulletin. Dr. Vollenweider has been invited to act as Guest-Editor.

During the reporting period, a major study on Canadian lakes has been completed in collaboration with Ms. L. Janus. The study was aimed at evaluating the transferability of the OECD results to a new set of lakes. This study showed that, in principle, the OECD relationships are valid over a large spectrum of different lake types, but that the application in particular cases must be done with caution.

Apart from these activities, Dr. Vollenweider has continued to assist and advise scientists around the world in eutrophication research problems and has been involved in research programs of the Biology Department of McMaster University, of which he is an associate.



## WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

In October 1974, the Canada Centre for Inland Waters was designated by the World Health Organization as its Collaborating Centre on Surface and Ground Water Quality (WHO/CC). The main function of the WHO/CC is (i) coordination of international technical assistance programs to the developing countries; and (ii) representation of Canada's freshwater interests in international forum.

In January 1976, the WHO/CC had initiated the publication of a quarterly journal WATER QUALITY BULLETIN, devoted to reviews of water management practices around the world. Furthermore, as of January 1977, the WHO/CC has assumed the responsibility of coordinating the establishment of a world-wide network of water quality monitoring stations on major rivers, lakes and aquifers around the world. The network is an integral component of the United Nations Global Environmental Monitoring System (GEMS). The main objective of this program is monitoring the long-term trends in environmental pollution.

The following is a brief review of the main activities of the WHO/CC during the year under review.

### GEMS/WATER

By the end of 1981, close to 300 monitoring stations on major rivers, lakes and aquifers in 40 countries around the world were established and reporting water quality data. Moreover, two training courses in general aspects of GEMS/WATER operation were organized in Africa: the first one was held in January in Dakar, Senegal, on behalf of 10 French-speaking countries of Africa and the second in November in Nairobi, Kenya, for the benefit of 15 English-speaking countries of Africa. A specialized training course in GEMS/WATER Analytical Quality Control (AQC) was held in December in Nagpur, India, for the benefit of the countries of Southeast Asia.



Some of the participants at the GEMS/WATER Training Course held in Dakar, Senegal, January 1981



A class scene from a GEMS/WATER training course held in Nairobi, Kenya, November 1981

Early in January 1981, the 340-page GEMS/WATER Operational Guide was published in French (GEMS/EAU Guide d'Utilisation) in time for distribution at the training course in Dakar. In June 1981, a new 40-page chapter on Sediment Analysis was added as the seventh chapter to the GEMS/WATER Operational Guide.

### **Water Quality Bulletin**

Four quarterly issues of the Bulletin, in separate English and French editions, were published as scheduled. They were devoted to the following themes: (1) Groundwater Management - Part 2; (2) Pollutants in Water and Sediments; (3) and (4) Eutrophication: A Global Problem, Parts 1 and 2 respectively. In all, 35 articles were published, written by 48 authors and co-authors from the following 14 countries: Argentina, Australia, Canada, Denmark, Germany (Democratic Republic), Germany (Federal Republic), Italy, Mexico, Norway, Poland, Sweden, Switzerland, USA, and USSR. Moreover, articles were published by the representatives of the OECD, UNICEF and the United Nations Division of Natural Resources and Energy on the activities of these international organizations. Noteworthy is the significant increase in the number of pages published, from 104 pages in 1980 to 160 pages in 1981.

### **Foreign Visitors and Consultants**

During the year, study and discussion programs for 36 foreign scientists from the following 15 countries were organized: Australia, Colombia, France, Germany (Democratic Republic), Germany (Federal Republic), Italy, Japan, Kuwait, Nigeria, South Africa, Sweden, Switzerland, Thailand, United Kingdom, and Uruguay. Requests for consultancies to the following organizations were processed: I.N.C.Y.T.H., Buenos Aires, Argentina; WHO Headquarters, Geneva, Switzerland; WHO/UNESCO, Nairobi, Kenya.

### **Technical Assistance**

Inquiries received from around the world, particularly from the developing countries on different aspects of problems of water management, have been responded to.

## HABITAT STUDIES (ECS-552)

With the developing shift towards ecosystem management in the Great Lakes Basin, and improved water quality conditions, a greater emphasis is now being placed on attempts to rehabilitate a number of important fish stocks. In particular, these include both lake trout (salvelinus namaycush) and whitefish (coregonus clupeaformis), and it should be possible to re-establish self-sustaining populations of these species now that lamprey control has become reasonably effective. One of the prime objectives of fisheries management in the Great Lakes is to increase substantially the rate and success of natural reproduction, but this is dependent, in part, upon both the availability and use of suitable spawning and nursery sites.

After a major absence of most stocks of these species during the past 30 to 40 years, changes in mainlake and nearshore water quality, and the effects of changing land-use and shoreline development, there appear to be problems in achieving successful reproduction and re-use of historic spawning sites. The reasons for this are not clear, and it is therefore important to define those habitat characteristics which are most likely to attract spawning fish and which will support the greatest survival of eggs and fry.

Most whitefish and lake trout spawning habitats are limited to the shallow nearshore zone in the Great Lakes, where the environment is particularly sensitive not only to fluctuations in the natural climatological regime but, also, to the effects of shoreline modification and the impacts of point source discharge of pollutants. Once the prime characteristics of suitable habitats can be defined, it should be possible to improve environmental management of the shoreline and nearshore zone by instituting practices which are designed to protect or enhance existing (suitable) sites, and possibly to create additional, artificial, habitats at new locations.

During the past three summers, underwater television and photographic data have been collected to document substrate characteristics over type transects at a number of historic spawning sites in Lake Ontario and the Bay of Quinte, the west side of Georgian Bay and South Bay (Manitoulin Island), and along the north shore of Lake Superior.

The spawning sites are characterized by a wide range of substrates which comprise delta fans, modern beach gravels, relict gravels, eroded glacial end- and ground-moraines and drumlins, scree and talus slopes, and bedrock exposures. Some of the historic sites were not characterized by coarse-grained materials and this has raised the possibility that muds, clays and sandy materials may prove useable as spawning substrates when "supported" by other special site-specific conditions.



There was little evidence of degradation at most of the sites in the upper lakes although weed cover and "siltation" in parts of South Bay (Manitoulin Island) and southern Georgian Bay may indicate a recent and significant degradation of site conditions. Weed cover and "siltation" were also noticeable at sites in Lake Ontario and the Bay of Quinte, and it is probable that recent changes at some of the historic Lake Ontario sites may make it impossible to consider their rehabilitation.

Variations in the fall, winter and spring climatological regime in the Great Lakes indicate that year-to-year changes are great enough at many potential spawning sites to impair the reliability of hatch and fry development. It is also possible that "preferred" spawning sites may be unusable in some years, because of severe storm activity (or other conditions) and that spawning stocks may seek alternative ("second choice") locations.

In any one year, it is therefore essential that self-sustaining stocks (particularly lake trout) should have access to a number of "first choice" spawning sites and a number of "second choice" alternative sites. In addition, the sites must be spaced apart so that they are subject to significantly different climatological conditions (e.g. fall storms, winter ice movement) and so that an unsuccessful development at one spawning site is not characteristic of all other sites as well.

Lake trout, like most other salmonids, are considered to be gang spawners and, under normal conditions, it would be expected that large groups of males and females would spawn together over clean (or cleaned) cobble-gravel substrates, distributing large numbers of fertilized eggs over a relatively confined area. By this means, although many eggs can be placed on unsuitable substrates, a large number would also remain in an appropriate microhabitat. On the basis of existing microhabitat observations, however, this does not appear to be characteristic of the behaviour of the new small stocks of lake trout. Some of these observations suggest that small numbers of individuals may make repeated but limited egg releases over a variety of substrates, and that a high proportion of the eggs are likely to be distributed in an unsuitable microhabitat.

Thus it is possible, in the microhabitat of a spawning site, that successful use may be "keyed" not only to a (regionally) suitable location but also to the substrate suitability ratio (area of potentially "good" substrate: area of adjacent or surrounding unsuitable substrate), stock size and egg density. If small rehabilitating stocks do not "key" well to available microhabitat, the potential for successful egg development and fry production is obviously much reduced.

Studies on the suitability of lake trout spawning sites and successful reproduction therefore involve an analysis of both habitat conditions and behavioural characteristics.

Because the coarse substrates of spawning sites are characteristic of a variety of geologically different deposits, it is possible that behavioural aspects of successful site-use may differ significantly from location to location and may thus become a distinguishing characteristic of individual stocks.

The study of whitefish spawning in the Great Lakes has been even more difficult than that of lake trout and, although the general proximity of many historical whitefish spawning areas is well known, the combination of small numbers of fish and adverse environmental conditions have made field observations extremely difficult in both South Bay and eastern Lake Ontario (where there may be a small river-run stock which spawns at the mouth of the Trent River as well as a stock which spawns at shallow depths along the south shore of Prince Edward County).

Whitefish eggs are more robust than lake trout eggs and, hydraulically, they behave like the most easily mobile sand grains. Thus eggs spawned under the turbulent conditions of river flow or near-shore wave action may be expected to disperse rapidly from source and may perhaps migrate to local sand bars or nearshore sand deposits, or they may become entrapped in the pitted and jointed surface of the bed-rock. This means that, unlike lake trout eggs (which can remain distributed at densities  $>100$  eggs  $m^{-2}$ ), whitefish eggs are likely to occur at densities which may be several orders of magnitude less. In order to study the significance of habitat control on the successful spawning and egg development of whitefish, it is necessary, therefore, to be very precise about the depth and location of spawning fish.

Between 1979 and 1980, fall catches (tagging) of whitefish indicated the presence of only very small numbers of the stock in the Bay of Quinte and eastern Lake Ontario area. Because of this, neither acoustic nor optical survey techniques proved successful as a means of identifying this species at spawning time. An attempt was made to identify spawning stocks in South Bay but a dramatic collapse in this well-established stock also rendered this attempt unsuccessful. During the fall of 1981, however, substantially increased numbers of whitefish were caught and tagged in the Bay of Quinte and along the south shore of Prince Edward County. As a result of this, it is expected that a more successful attempt to locate spawning whitefish can be made in the fall of 1982, and experiments will be carried out in the summer of 1982 in the hope of significantly improving the use of acoustic fish location techniques.

Because of a lack of existing winter water temperature data, temperature records are being collected from the nearshore zone in both eastern and western Lake Ontario to characterize the thermal regime at potential spawning sites during the period of egg development and fry hatch.

From an assessment of preliminary data it is clear that, at least in western Lake Ontario, the fall period is characterized by events of severe and rapid temperature change (e.g. 17°C to 8.5°C in less than 4 hours) which could well influence both spawning success and egg survival. The development of the thermal bar, in the spring, may also significantly affect the survival of young fry.

At the eastern end of the lake, ice development may present a different problem. Ice movement has been found to affect parts of the nearshore to water depths of 4 to 5 m along the south shore of Prince Edward County, and to depths of 10 m and greater around parts of the Duck Island area. The displacement of substrate containing spawned eggs by these mechanisms would almost certainly result in severely reduced survival, if not in an entire loss of eggs.

The relationships between meteorological events and spawning activity are not clearly understood and because there is a close relationship between weather conditions, habitat availability and the run of spawning fish, Lake Ontario catch data from the Cape Vincent and Glenora Fisheries Stations are being compared with meteorological records.

In addition, a co-operative study with the New York Department of Environmental Conservation has been undertaken in Seneca Lake where fall catch data and meteorological records are available over a period of about 40 years and where fish catch can be related to the use of unique deep-water spawning habitat.

Based on these and other data sets, the significance of various habitat characteristics is being assessed, using a form of matrix analysis. Because of the availability of a slightly better data base, lake trout habitat is being assessed first.



**ENVIRONMENTAL CONTAMINANTS DIVISION**



Contamination adversely affects many uses of Canada's fresh-water resources. Action to alleviate public concern about contamination and/or to reduce or eliminate contamination is predicated upon an in-depth knowledge of the pathways and thus the fate of contaminants in aquatic ecosystems. The Environmental Contaminants Division conducts research to resolve these pathways. The fate of contaminants must be known to determine exposure and estimate hazard to biota, including man. Three groupings of contaminants are investigated - organics, inorganics and radionuclides. Research encompasses contaminant transformations, translocation, air-water interactions, sediment-water interactions and bioaccumulation.

The Environmental Contaminants Division (ECD) consists of four sections: Organics-Properties, Organics-Pathways, Inorganics, and Radionuclides. Although the objectives of each Section are separated below, there is overlap between Sections. Information arrived at in one Section may be equally valuable to the achievement of goals in another Section. No individual project can lead to a complete modelling of the fate and impact of a contaminant released to an aquatic ecosystem. Information from several projects can lead to such predictions. The same applies to classical modelling of the fate of contaminants in an already polluted aquatic ecosystem. The former models require toxicology input. The latter models require input from biologists, aquatic ecologists and physical limnologists. Such input is obtained by cooperation with other Divisions within NWRI.

Dr. R.J. Allan and Mrs. A. Mudroch have been closely involved with the Canada-U.S. Niagara River Study Committee and have made several presentations on contaminant problems in the Niagara Frontier. They are co-leaders of the National Water Research Institute's Niagara River Study Group. The early results of this research will be presented at a special symposium at the International Association of Great Lakes Research (IAGLR) meeting in May in Sault Ste. Marie. Dr. Allan continued as Co-Chairman of the Canada-Ontario Steering Committee supervising research to ameliorate mercury pollution in the English-Wabigoon River system of northwestern Ontario. A comprehensive final report is nearing completion. Dr. W.M.J. Strachan continued as Chairman of the Great Lakes Water Quality Agreement, Aquatic Ecosystems Objectives Committee. An annual report was presented to the International Joint Commission. Dr. Strachan also continued to serve on the Organization for Economic Cooperation and Development Chemical Testing Program Committee on Test Guidelines. A comprehensive OECD Manual on Testing Guidelines was released this year. Dr. R.J. Maguire continued to serve on the National Research Council Environmental Secretariat Panel on Aminocarb. A Criteria publication will appear in the near future. Dr. D.S. Jeffries became Chairman of the Algoma Watershed Acid Rain Research Steering Committee. A series of special publications based on the multidisciplinary research conducted in the watershed is planned.



Special note should be made of the initiation of several field-oriented studies to resolve the questions about the past, present and future contamination of Lake Ontario from sources in the Niagara River and its tributaries. Dr. D. Jeffries joined ECD to lead studies dealing with the geochemical controls of acidification of drainage basins. Dr. W.M.J. Strachan spent most of the year seconded to the new Toxic Chemicals Management Centre in Ottawa. While there he contributed to developing the objectives and priorities of the Centre. On an academic level the most significant event was Dr. Y.K. Chau's gaining of the DSc degree from Liverpool University.

Drs. D.L. Liu and Y.K. Chau presented papers at three foreign conferences, the former in Scotland and the latter in Italy and the Netherlands. Twelve other conference presentations were made in Canada and the United States.

### **ORGANICS-PROPERTIES SECTION**

The objective of this Section is to investigate the chemical and physical characteristics of organic contaminants which govern their interactions with biota and abiotic material in aquatic ecosystems. Structure-activity (property - biological effect) correlations are established for a variety of contaminants with a view to establishing general underlying principles of properties and effects. Studies in this area can be grouped into bulk properties such as lipid-water or sediment-water partition coefficients; molecular properties such as ionization potentials; and reactions such as hydrolysis, chlorination and photodegradation. Considerable effort is devoted to the identification of contaminants and to their toxicity to bacteria and fungi. Projects also investigate the persistence and degradation of organic material in the aquatic environment with an emphasis on microbiological, photochemical, and bioaccumulation processes.

### **Structure-Activity**

Structure-activity correlations are important tools for the identification and prediction of biologically-active structures in the development of medicinal compounds. In order to assess the environmental hazard potential of new contaminants and materials in a time- and cost-saving fashion, available biochemical data are correlated with the physical and chemical characteristics and properties to arrive at the structure-activity correlations for the compounds to be determined. The necessity for such a program has also been recognized by the Integrated Planning and Management Activity (goal 5, A-Base Review) and has been identified as a Research Need by the Research Advisory Board.

The impact and pathways of organic contaminants in aquatic systems are determined by three distinct properties: toxicity, bioaccumulation potential, and persistence. Each of these properties is

determined by molecular characteristics and, in principle, can be predicted from the known values of these for related compounds. So far, notable progress has been made in the correlations of bioaccumulation potentials and bioconcentration factors with the octanol-water partition coefficient. The lipophilicity of compounds is also strongly related to their water solubility and fugacity, hence also to toxicity.

In collaboration with scientists of the Great Lakes Fisheries Research Branch, triplicate LD<sub>50</sub> (lethal dose to 50% of population) values were determined for 10 para-substituted phenols and 12 chlorobenzenes, by intraperitoneal injection (IPI) to small (~25 g) rainbow trout (*Salmo gairdneri*). Oral LD<sub>50</sub> (OI) values of four of the chlorobenzenes and five of the phenols were also determined, as well as 96-hr lethal concentrations (96LC<sub>50</sub>) for some phenols.

The 120-hr LD<sub>50</sub>s by IPI for the chlorobenzenes ranged from 5.1 mmol/kg for 1,2,3,4-tetrachlorobenzene to 30.5 mmol/kg for 1,3,5-trichlorobenzene. The results were highly reproducible with standard deviations ranging from 2 to 9% of the means. The OI LD<sub>50</sub>s for the chlorobenzenes were consistently 22 to 30% higher than the IPI LD<sub>50</sub>s. There was, however, a linear correlation between the two (IPI LD<sub>50</sub> = 0.55 + 0.76 OI LD<sub>50</sub>;  $r^2 = 0.99$ ;  $s_d = 0.02$ ;  $N = 4$ ) that was significant at the 0.05 probability level.

The IPI LD<sub>50</sub>s for phenols were lower than those for chlorobenzenes, ranging from 0.19 mmol/kg for p-cyanophenol to 4.34 mmol/kg for phenol. The results were also more variable, with standard deviations ranging from six to 35% of means. Once again OI LD<sub>50</sub>s were higher than IPI LD<sub>50</sub>s, by 14 to 45% and a statistically-significant correlation ( $P = 0.05$ ) between the two was evident (IPI LD<sub>50</sub> = 0.044 + 0.781 OI LD<sub>50</sub>;  $r^2 = 0.99$ ;  $s_b = 0.04$ ;  $N = 5$ ). The LC<sub>50</sub>s for the five phenols tested ranged from 0.0012 mM for p-(methylamino) phenol sulphate to 0.103 mM for phenol. A curvilinear relationship appears to exist between LC<sub>50</sub>s and both OI and IPI LD<sub>50</sub>s but there were insufficient data for a definitive correlation.

### PCBs in the Great Lakes

One of the Department of the Environment's mandates is to study environmental contaminants - particularly in transboundary waters. To date our study has focussed on the Niagara River and adjacent Lake Ontario, and it is clear that most of the persistent organic chemicals present in this river and lake originate in the United States.

In addition to tracing contaminant sources, a major objective of this study is to develop a better understanding of the movement and pathways of persistent organics and, if possible, to relate the ultimate fate of the chemical to its chemical and physical properties. By measuring concentrations of specific chemicals in the various aquatic

compartments an estimate of human exposure via water and fish consumption can also be made.

After development of sufficiently sensitive analytical techniques for chlorinated organics in water, sediments and fish, samples were analyzed from throughout the Canadian segment of the Great Lakes. The first group of compounds for which analyses are complete are the chlorobenzenes, CBs. This study showed that Lake Ontario water, sediments and fish contained much higher CB concentrations (10 to 20 times) than samples from Lakes Superior, Huron or Erie (see Table). A sampling cruise up the Niagara River showed that the major sources of CBs to Lake Ontario were chemical plant effluents and leachates from waste disposal sites (e.g., Love Canal) located in the United States.

Further work being carried out on CBs in the Niagara River/Lake Ontario vicinity includes: mapping of the CB distribution in Lake Ontario sediments, dating CB inputs from the Niagara River by sediment core analysis, and analyzing CB concentrations in various components of the aquatic food chain. In addition, the concentration of specific toxic PCB isomers in these samples will be determined in the next few months.

To conclude earlier work, two studies were completed on chlorinated by-products from the reaction of chlorine with naturally occurring organic material under conditions used in drinking water treatment.

#### **A Comparison of Lake Ontario and Lake Erie Chlorobenzene Concentrations**

Compound*	Water Concentration (ppt)		Sediment Concentration (ppb)		Fish Concentration (ppb)	
	L.Ontario	L.Erie	L.Ontario	L.Erie	L.Ontario	L.Erie
1,4 DCB	45	4	94	9	4	4
1,2,4 TCB	0.6	0.2	94	3	5	0.5
1,2,3,4 TeCB	0.1	0.05	33	0.7	12	0.3
QCB	0.2	0.04	32	1	16	0.6
HCB	0.06	0.04	97	3	127	8

\* 1,4-Dichlorobenzene; 1,2,4-Trichlorobenzene;  
1,2,3,4-Tetrachlorobenzene; Pentachlorobenzene;  
Hexachlorobenzene.

#### **Identification of Contaminant Sources**

Many toxic and carcinogenic organics have been found in surface and municipal waters. It is important to identify such contaminants and their sources, pathways, and sinks so that corrective measures



can be undertaken where necessary. Work in the Niagara River and its tributaries have shown the presence of a large number of organic contaminants. This study is an integral part of several ongoing investigations on the identification of the sources, pathways and sinks of such contaminants.

Effluents of Cyanamid Chemical Co. produce point source loadings of methylene chloride, carbon disulfide, dibromomethane and bromotrichloromethane to the Welland River. Such effluents also add significant levels of trichloroethylene, carbon tetrachloride, 1,1,1-trichloroethane and tap water related trihalomethanes to existing volatile levels in the river.

In 1981, Ford Motor Co. had an active outfall to the Welland River consisting mainly of tap water which also contained moderate levels of trichloroethylene, perchloroethylene, tetrachloroethane and a substantial level of dichlorodifluoromethane.

Although several of the detected compounds are known or suspected to be animal mutagens and carcinogens, and therefore pose health hazards also to humans either directly through contamination of potable water or indirectly through bioaccumulation in fish, this is not likely to be of concern here because of the high dilution rates, degradation and volatilization, such that the concentrations of most of the compounds in the Chippawa power channel are near background levels. The relatively high levels of chlorodibromomethane in the water at the Adam Beck reservoir are likely to result from several discharges along the Welland River-Chippawa power channel system including those of the Cyanamid plants. Of possible concern are the considerable discharges of carbon disulfide. Although this compound has been observed as a natural product of the sulfur cycle in marine systems, its concentrations there are in the order of  $1 \text{ ng} \cdot \text{L}^{-1}$ , approximately 1000-fold less than in Thompson Creek water. Moreover, it is unknown whether or not  $\text{CS}_2$  is also a natural constituent of freshwater. Carbon disulfide is a well-known poison to many mammalian species with neurotoxic effects upon chronic exposure.

### **Bacterial Metabolism of PCBs**

Although chlorinated biphenyls are among the most persistent of environmental contaminants, certain of them are susceptible to bacterial degradation at least to a limited degree. The aim of this study has been to extend our knowledge of this topic, and to investigate possible further non-biological transformations which the products of the initial biochemical reactions may undergo.

For this purpose we have used a bacterial culture which is capable of degrading chlorinated biphenyls. It grows rapidly in a mineral salt medium with biphenyl as its only carbon and energy source. In most experiments the organisms have been removed from the growth medium by centrifugation and suspended in phosphate buffer.

Using the Gilson apparatus, two monochlorobiphenyls and six dichlorobiphenyls were found to undergo biological oxidation as shown by oxygen uptake. One dichlorobiphenyl (the 2,6-isomer) and all more highly chlorinated biphenyls tested appeared not to be attacked.

2,4'-dichlorobiphenyl was converted to a bright yellow compound, which on the basis of reports in the literature is probably produced by meta-cleavage of one of the two rings. A similar product is obtained from Arochlor 1016 (Monsanto), a mixture of several chlorinated biphenyls. These products are bleached in long wavelength ultraviolet light or sunlight. The nature of this reaction is being investigated.

With Arochlor 1221, a mixture of less highly chlorinated biphenyls, a brownish product is formed which darkens in ultraviolet light, and more slowly on standing at room temperature, suggesting that polymerization to material resembling humic acid occurs. This reaction is also being investigated further.

These studies lead to the tentative conclusion that the products of bacterial degradation of chlorinated biphenyls undergo photochemical and spontaneous reactions leading to their further degradation and polymerization.

### Biodegradation of Organic Contaminants

Toxicity and biodegradability are important factors governing the fate and behaviour of an organic compound in the environment; the degree of bioaccumulation of a toxic substance in the food-chain also depends on these parameters. Such investigations are highly relevant to hazard assessment, an aspect of the Environmental Contaminants Act. Microbial degradation, in particular, provides a major route for the removal of many contaminants from the environment. Chemical toxicity, on the other hand, may affect the microbial degradation process and the operation of the food-chain in aquatic ecosystems.

Because of the many variables involved, it is impractical to study a chemical's biodegradation in all natural environments. A standard laboratory fermentor system has been developed to examine a compound's degradation processes induced by microorganisms from sediment, soil and activated sludge. The study has determined the biodegradability of several priority chemicals listed under the Environmental Contaminants Act.

The standard laboratory procedure, capable of accurately predicting the persistence of the test chemical in various aquatic compartments, is based on the measurement of the primary degradation rates of such substance in cyclone fermentors under aerobic and anaerobic conditions, with and without cometabolites (see Table). The biocides fenitrothion and 2,4-D were tested as examples in the system, and results indicated that the former was less stable under anaerobic conditions and the latter was more persistent under the same environmental condition.

In addition, several other priority chemicals, including pentachlorophenol (biocide), carbaryl (insecticide) and p-nitrophenol (industrial chemical), were also tested in the system. The calculated relative persistence was compared with the published field data and good agreement was observed. The biodegradation of Arochlor 1221 type PCBs in wastewater has also been studied, as well as the role of fungi in the decomposition of pentachlorophenol.

#### Effect of Environmental Factors on Fenitrothion and 2,4-D Degradation

	Aerobic		
	Control	Metabolism*	Cometabolism*
Fenitrothion			
$10^{-3} \text{ k, h}^{-1}$	2.3	0.40	5.3
half-life, day	13.0	73.0	5.5
r	0.66	0.89	0.98
2,4-D			
$10^{-3} \text{ k, h}^{-1}$	0.30	9.5	16.2**
half-life, day	97.0	3.1	1.8
r	0.97	1.0	0.98
	Anaerobic		
	Control	Metabolism*	Cometabolism*
Fenitrothion			
$10^{-3} \text{ k, h}^{-1}$	1.7	3.9	38
half-life, day	17.0	9.8	1.0
r	0.77	0.98	0.86
2,4-D			
$10^{-3} \text{ k, h}^{-1}$	0.24	0.21	0.42
half-life, day	120.0	135.0	69.0
r	0.96	0.70	0.98

\* Calculated from percent of control at the same time and oxidation state.

\*\* Only the last three data points were employed to account for acclimation.

Two biological tests based on the measurement of the interaction between the toxicant and the bacterial response were developed for assessment of a chemical's toxicity. The tests are economical, simple, and sensitive when compared with conventional methods. Consequently, they have potential for use in structure-toxicity studies and for screening a large number of samples for the presence of toxic chemicals.



Since the chemical and biological activity in sediment may affect the fate and pathway of a contaminant in the aquatic environment, a field method based on the measurement of the reaction between resazurin and such activity was developed. This highly reproducible test offers promise of a method for ascertaining different types of activities in the sediments.

### Chlorinated Hydrocarbons at the Air-Water Interface

This study consists of two separate investigations. The first of these is a determination of the equilibrium distribution of a few representative toxic compounds between water and the insoluble organic phase which is inevitably present in natural waters - often as a slick floating on the surface. The second is a measurement of the transport of the same compounds from one phase to another - the air being included as a phase. In other words, the transport properties refer to a system on its way to a final equilibrium state.

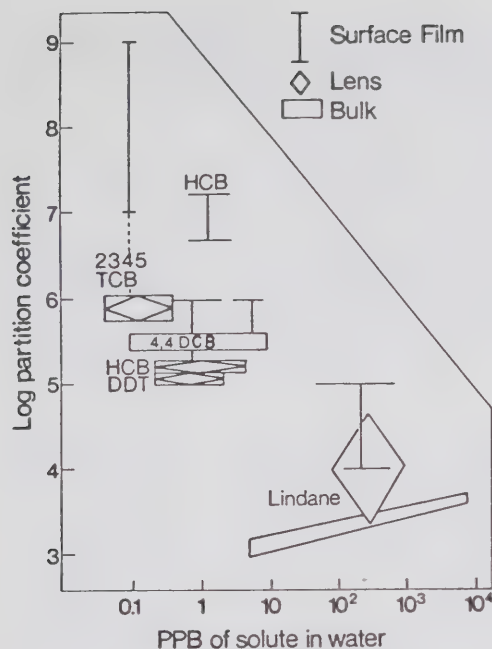
The quantities measured in the course of this work include vapour pressures, partitioning between the model lipid octanol and water, and hydrocarbon concentrations in the air and surface films over natural waters.

Of the five chlorinated hydrocarbons whose octanol-water partition coefficients have been measured, three have been found to be much more strongly partitioned into a thin film of octanol on the surface of water than into bulk octanol in equilibrium with water. The results of three types of measurement are shown in the Figure:

- a) Conventionally determined partition coefficients between octanol and water.
- b) Partitioning when the octanol is in the form of a small lens floating on water, and which should give the same results as (a).
- c) Partitioning into octanol in the form of a monomolecular layer of octanol surrounding the lens in (b).

It can be seen that enhanced partitioning in surface films is observed for lindane, hexachlorobenzene and 2,3,4,5-tetrachlorobiphenyl. This surprising and important effect was not observed for these compounds in thin films of oleic acid, however, and remains to be confirmed outside this laboratory.

Future work will consist of laboratory vapour pressure measurements on chlorinated hydrocarbons and analyses of samples taken from the Grand and the Niagara Rivers and from the air immediately over the surface of each river.



The relationship between concentration and octanol-water partition coefficients for HCB, 4,4'-DCB and DDT.

## ORGANICS-PATHWAYS SECTION

The objective of this Section is to resolve the entry, fate, distribution, and transfer of organic contaminants in the aquatic ecosystems. Research is conducted at specific polluted aquatic ecosystems, in experimental ponds, and in the laboratory. Projects include studies in large and small river-lake systems. Experimental additions of organic contaminants are made to a series of artificial ponds located near Hamilton to examine intercompartmental transfer (water, suspended sediment, sediment, benthic fauna, and flora) and effects of organic contaminants. Atmospheric input of organic contaminants to the aquatic environment is being studied in the Great Lakes drainage basin.

### Benthos Uptake of Organics at Niagara River Mouth

Studies by all levels of government in both Canada and the United States have established the Niagara River as a major contributor of toxic organic loading to Lake Ontario. This study addresses the fate of some of these substances in Lake Ontario and, in particular, their incorporation into the aquatic food chain via benthic organisms, since this route is a suspected avenue for the contamination of commercial and sports fisheries in Lake Ontario.

The 1981 study was considered as a preliminary investigation to learn if a more in-depth study was justified. The answers to several specific questions will help to guide the direction of ongoing studies in 1982. The study focussed on three main areas:

1. Whether organic contaminants are carried into Lake Ontario primarily via suspended sediments and, if so, whether their distribution among different particle sizes and types is significant.

2. Are organic contaminants in surficial sediments of the dispersal area of the Niagara River plume bioaccumulated in benthic animals?
3. Which organic contaminants are significantly involved in the above processes?

Several other studies on different aspects of the Niagara River contamination of Lake Ontario were currently in progress at NWRI. This work was coordinated with these studies, especially in the choice of sample locations, in order to facilitate inter-study comparisons and conclusions.

Suspended solids were collected with a plankton net in the Niagara River near Niagara-on-the-Lake in June, July and September, 1981. The suspended solids were divided into six fractions between 38 and 841  $\mu\text{m}$  by wet sieving. High concentrations of PCBs and chlorobenzenes were observed on the suspended solids. A somewhat surprising result was the detection of significantly higher concentrations of contaminants on the larger particles, since purely physical considerations would predict the smallest particles to have the highest concentrations.

Surficial sediment, water, pore water and benthic organisms were collected from five sites in Lake Ontario near the Niagara River mouth. Fish (Lake Trout), mysids and deep water zooplankton were also obtained from one station in July. Amphipods and oligochaetes were selected as benthic organisms for analysis, based on the frequency of occurrence at all stations and differences in habitat. Although chironomids were also found at all stations, their numbers were not sufficient for analysis. Concentrations of organochlorine contaminants in surficial sediments tended to fall between the values for the largest and smallest particles of Niagara River suspended sediment and exhibited a significant bioaccumulation in amphipods of the more persistent contaminants such as PCBs (x35), whereas less refractor contaminants such as hexachlorobutadiene showed no trend to bioaccumulation (see Table).

Study plans for 1982-83 reflect indications that the bulk of the contaminant load may be associated with the dissolved phase rather than the suspended solids. Thus, to determine the fate of these substances in Lake Ontario, it is necessary to follow the Niagara plume rather than suspended solids. Intensive sampling on transects across the Niagara River plume in Lake Ontario will be carried out on several occasions. Transmissometer and EBT profiles will be obtained to define the location of the plume. A fast analysis for one or two selected organochlorine contaminants will be performed on the samples with more detailed analyses in selected samples.



**Concentrations of Four Organochlorine Contaminants in Niagara River Suspended Sediments and Receiving Zone Compartments in Lake Ontario Near Niagara River Mouth April-May, 1981 (ng/g dry weight basis).**

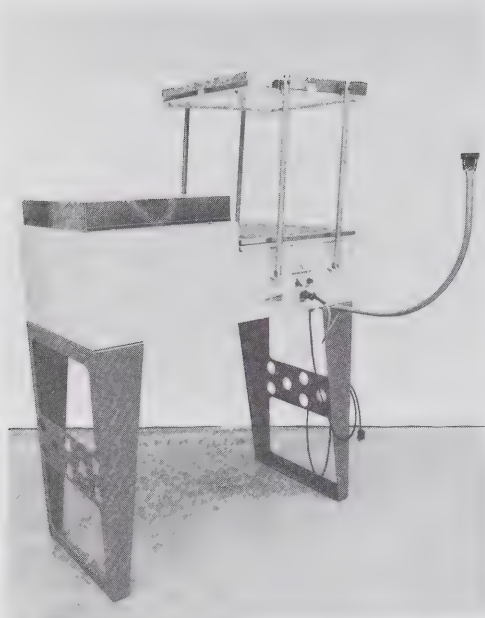
Location	Sample Compartment	Hexachloro-Butadiene	Hexachloro-Benzene	Total PCB's	Mirex
Niagara River at N.O.T.L.	Sus. Sed. 38-74 $\mu$ m	11	17	639	49
Niagara River at N.O.T.L.	Sus. Sed. 841 $\mu$ m	710	92	5488	434
Lake Ontario St. #207	Surficial sediment	31	260	680	3
Lake Ontario St. #207	Oligochaetes	60	100	2200	10
Lake Ontario St. #207	Amphipods	20	390	24000	50

**Toxic Organics in Precipitation**

Toxic organic substances, particularly the persistent organochlorine pesticides and PCBs, have been identified in wetfall in the Great Lakes area and elsewhere. Indications of deposition in this manner are such that, for PCBs, BHC and DDT, this is the major input of these materials to Lake Superior, probably the major route for Lake Huron, and certainly a substantial mode for Lakes Ontario, Erie and Michigan.

A wetfall sampler was designed and built under an Environmental Contaminants Contract Fund and prototypes were evaluated in both the field and laboratory. The purpose of this report is to summarize the results obtained and to recommend whether such samplers should be employed in the larger scale CANSOC program.

The sampler is a stainless steel funnel (0.209 m<sup>2</sup>) with an automated lid which opens when a sensor detects moisture. All sampler parts in contact with the rain are heavily teflon-coated. Extraneous splashing into the funnel is prevented by covering all exposed horizontal surfaces with stainless steel mesh. A teflon column (25 cm x 2 cm i.d.) is attached to the funnel. It is partly filled with XAD resin. Resins with samples adsorbed were extruded and analyzed by IWD-WQB (Ontario Region).



Wetfall Sampler especially designed and built for the Environmental Contaminants Division.

The samplers and procedures were tested (triplicate) for recovery in the laboratory. Table 1 presents the recoveries for those substances tested. In addition to the recoveries, the sampler was evaluated in the field. Three samplers and a rain gauge were located at Fifty Mile Point (F samples) near Hamilton, Ontario, and later at the Turkey Lake field station (T samples) near Sault Ste. Marie, Ontario. Rain volumes sampled (1.0 to 17.9 L) were determined from tipping bucket rain gauge data and the sampler area; they correspond to discrete rain events. A number of samples were not suitable because of electrical or mechanical problems; these have been remedied. A major problem was the occasional drying-out of part of the columns during the heat of summer; solutions to this are under consideration.

**TABLE 1. Recovery of Organochlorines from Sampler**

Compound	Theoretical Concentration ( $\mu\text{g/L}$ )	Observed Concentration ( $\mu\text{g/L}$ )	SD (% RSD)	Recovery (%)
Hexachlorobenzene	0.123	0.076	0.007 (9)	62
Lindane	0.254	0.106	0.007 (7)	42
Heptachlor	0.117	0.029	0.026 (89)	25
Aldrin	0.067	0.045	0.007 (16)	67
$\alpha$ -chlordane	0.478	0.342	0.022 (6)	72
$\gamma$ -chlordane	0.713	0.736	0.035 (5)	103
Endosulfan	0.417	0.340	0.022 (6)	82
pp'DDE	0.542	0.285	0.025 (9)	53
pp'-DDD	0.413	0.288	0.010 (4)	70
pp'-DDT	0.363	0.206	0.016 (8)	57
Methoxychlor	0.505	0.292	0.034 (12)	58

Mean values for field samples are presented in Table 2 for those substances which consistently gave values statistically different from zero. Other sample sets have been collected and will be added to the table as they become available.

**TABLE 2. Significant Precipitation Results**

Sample	Concentrations in $\mu\text{g/L}$ (%RSD)		
	$\alpha$ -BHC	$\gamma$ -BHC	PCB
F1404	0.034 (49)	0.007 (21)	-
F2404	0.038 (15)	0.011 (15)	0.011 (8)
F0505	0.010 (31)	0.005 (35)	0.041 (10)*
T0206	0.005 (2)*	0.001 (4)*	0.001 (36)
T0406	0.025 (2)*	0.006 (3)*	0.008 (28)

\* Average and % RSD for duplicates; third value differed grossly from others.

No discernible pattern is apparent for precision for the above. For the three substances noted, therefore, a mean percent relative standard deviation of 20, 16 and 21% is reported for  $\alpha$ -BHC  $\gamma$ -BHC and PCB, respectively. The number of sample sets is small and final evaluation of the errors associated with the sampler will await further sets currently collected and undergoing analysis. A repeat is also being undertaken for the recovery tests. In the meantime, however, the apparatus and precipitation would seem to be an improvement over the much smaller collection sampler ( $0.06 \text{ m}^2$ ) and resultant volumes and frequencies of the CANSOC samples.

### Sediment-Water Partitioning of Organics

Knowledge of the distribution of chemicals in the environment is a prerequisite to the evaluation of the hazard they represent, and partitioning, transformation and transfer are among the primary factors which govern such distribution. Central to most descriptions of chemical behaviour is the aquatic segment of the ecosystem and, within that compartment, partitioning between the dissolved and adsorbed phases will be a major influence on the fate and behaviour of persistent, hydrophobic contaminants.

A number of empirical methods exist to estimate the sediment (or soil) - water partition constant, all of which assume that only the incorporated organic matter determines this constant. It has also been reported that such adsorption is a two-process mechanism; further, it is difficult to use these methods to predict results obtained in different studies employing different sediments or soils. The purpose of this



study is to investigate the suitability of these predictive approaches, particularly as they apply to the several size fractions of natural sediments.

Study progress was somewhat hindered by the secondment of one member of the study team. Preliminary tests, however, were undertaken to evaluate procedures. The 2,4,6,2',4',6'-hexachlorobiphenyl isomer (HCBP) was partitioned between whole sediment and either distilled water or 0.01 N NaCl. Two sediment samples were employed - one "high" in organic content (2.44% P.O.C.) and one "low" (0.84% P.O.C.). In addition, a more soluble organic substance, hexachlorobenzene (HCB), was examined using a different "high" organic sediment. Recovery of both organics from distilled water was: HCBP, 76% (range 69-82, n=4) and HCB, 76%, while from the total system it averaged 45% for HCBP and 71% for HCB.

#### Sediment Sorption of 2,4,6,2',4',6'-Hexachlorobiphenyl and Hexachlorobenzene

Sediment Type*	mg/L or mg/kg			Sorption	
	Susp. Solid Conc'n	Water Conc'n	Sediment Conc'n	$10^{-3}K_d$ ( $\pm\%$ RSD)	$10^{-6}K_{oc}$ ( $K_d \times 100/\%$ oc)
2,4,6,2',4',6'-Hexachlorobiphenyl					
LO	20,25	0.008,7	420,720	77( $\pm 44$ )	9.2
LO (saline)	18,41	0.006,5	480,270	69( $\pm 38$ )	8.2
HO-1	19-28	0.005-10	490-810	96( $\pm 29$ )	3.9
HO-1 (fines)	22-34	0.006-8	170-230	30( $\pm 22$ )	1.2
HO-1 (saline)	18,21	0.007,8	930-440	95( $\pm 64$ )	3.9
Hexachlorobenzene**					
HO-2	22,29	0.092,69	-, -	[8.4( $\pm 42$ )]	***
	15-28	0.058-104	268-679	5.1( $\pm 24$ )	***

\* LO - low organic sediment HO-1 - high organic sediment  
Sample 1, HO-2 wet sediment Sample 2 (76.1% water) used, fines were sieved as 45  $\mu$ m.

\*\* Water and sediment concentrations are presented as  $10^3 \times$  observed.

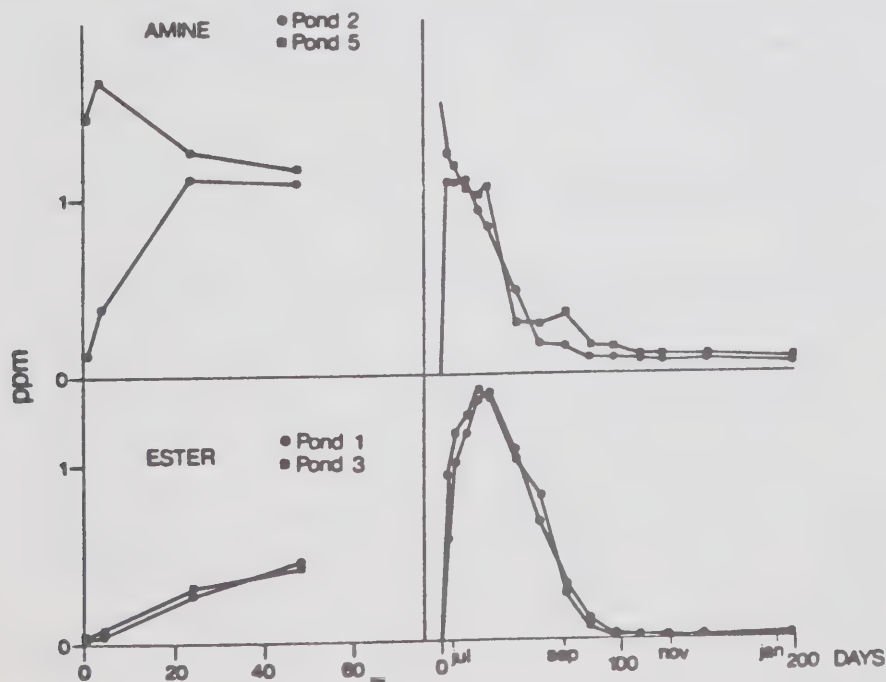
\*\*\* Organic content not determined.

Indications from the above are that considerable variability exists for results obtained under apparently similar conditions. Salinity does not appear to be a factor but the sediment size fraction does appear to be significant. Further investigation will include factors such as sorption on filters, homogeneity and preparation of sediment substrate, recovery of substances, particularly from the sediment, and possible volatilization of substances during removal of solvents.

## Contaminant Studies in Ponds

The pathways, fate and impact of contaminants are high priority issues concerning the Department and the Service. To address this concern, meso-ecosystems, i.e., lined ponds, have been developed. They allow the examination of the chemical and determination of biological changes in the system induced by the contaminant, without the removal of the chemical and elements of the biota from the system by currents and diffusion processes. In addition, the system has low environmental risk as the sediment and pond liners prevent contamination of adjacent soil and groundwater by the chemical under study. The herbicide, 2,4-D, extensively used in Canada for crop control, and in water to control weeds, is a toxicant as is its first breakdown product, 2,4-dichlorophenol (DCP); 2,4-D was chosen for a pond study. Samples have been collected and analyzed for 2,4-D and DCP in water, sediment, particulate material and selected biota. The biota monitored throughout the study period included protozooplankton, mesozooplankton, micro- and macrozoobenthos, phytoplankton, periphyton, fish, and macrophytes. In addition, water samples were analyzed for DO, nutrients, pH and major ions.

In July of 1981, the two control ponds of the 1980 series of tests were treated with the same formulation of 2,4-D to determine the degree of replication of the previous year's results. Concentrations of 2,4-D in the water column after the 1981 treatment followed the same trends as the 1980 values (see Figure). In the ester-treated ponds for both years, one half of the maximum concentrations were reached 55 days after treatment. This is the same time required by the amine-treated



The observed concentrations of 2,4-D in ponds treated as noted.

pond in 1981 to reach half of its maximum concentration. During the 1980 studies, 2,4-DCP persisted in the sediment and water column. In the 1981 studies, very little 2,4-DCP was detected. This difference was undoubtedly caused by the higher pHs in the ponds in 1981, which favour formation of the ionic form of the phenol. The ion will react faster photochemically than the undissociated parent phenol. For both years, 2,4-D concentrations in the sediment were higher in the ester-treated ponds relative to the amine-treated ponds. (The ester treatment used a pelletized formulation.) Also, there was uneven distribution of the 2,4-D on the sediment of all ponds.

All target plants, Myriophyllum spicatum, had succumbed within 14 days of treatment in both years. There was no gross depletion of oxygen except within 6 cm of the bottom once the plants had collapsed. This is contrary to some predictions made from laboratory studies and subsequent modelling. Also, there was no sudden release of nutrients from the decaying plants to produce algal blooms.

All water quality parameters (nutrients, etc.) experienced similar fluctuations throughout the course of the experiment, with the exception of alkalinity. This parameter increased in the two treated ponds of 1981 after the plants had fallen to the bottom of the ponds. This increase may have resulted from the decaying plants releasing  $\text{CaCO}_3$  they had encrusted on their leaves back into the system. This was partially confirmed by simultaneous increases in the Ca ion content of the water.

Fish toxicity of fingerlings over the first week after treatment was moderate (20%) in 1980 and very low in 1981. This difference resulted from there being less phenol present, and most of that which was in the water column being in the ionic form which is less toxic than the parent phenol.

Analytical methods have been modified and tested for the simultaneous extraction and analysis of 2,4-D and 2,4-DCP from clams, milfoil and fish.

### Accumulation and Degradation of Organic Contaminants in Fluvial Systems

Research into the transport and degradation of contaminants is needed in order to adequately assess risks from environmental pollution and is a high priority for both the Department and Service. In conjunction with laboratory studies, there is a need for field studies of the behaviour of contaminants under actual environmental conditions. As a step in meeting this need, the Canagagigue Creek Project was begun in 1979. The project has adopted the ecosystem approach and is attempting to determine the factors affecting the accumulation and disappearance of synthetic organic compounds introduced to the stream at the town of Elmira. Results for the first year's study indicated that chlorophenols were the most prominent contaminant at most times of the year. These



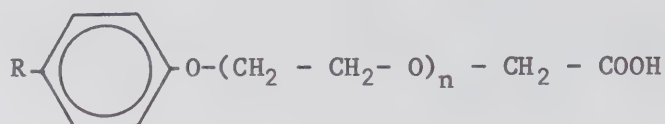
substances appear in the stream as a result of leaching activity in the area of a disused chemical waste dump. In addition, other synthetic organic compounds such as methyl thiobenzethiazole, MMBT, were observed in the discharge of a sewage treatment plant receiving industrial wastes. Also in the effluent of the sewage treatment plant, we observed unidentified acidic compounds at concentrations higher than the fatty acids. These compounds appeared to be the result of degradation of unidentified precursors in the treatment plant.

Research for FY 81-82 was planned to examine the above areas in greater detail. Specifically, the factors affecting the distribution and fate of MMBT and chlorophenols in the stream and biota were to be addressed and the identity and origin of the acidic compounds examined. In a related part of the study, the importance of photolysis in degrading TFM was to be assessed in Oakville Creek.

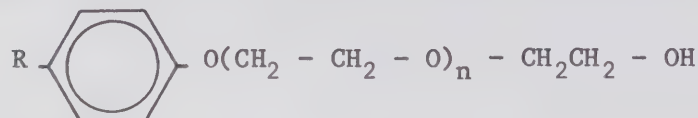
Several factors complicated the work this year. The first of these was the near total absence of MMBT from Canagagigue Creek. It appears that the chemical plant which is the source of this compound switched production to other materials. A determined effort to find another water soluble electron capture detector active compound in the stream at levels high enough to study volatilization failed. In any case, laboratory studies revealed that its vapour pressure is lower than anticipated and volatilization is probably not the major environmental route of disappearance for this compound. A study of the effect of humic compounds on the biodegradation of MMBT has revealed that fulvic acid enhances this degradation route.

A more serious problem involved the accidental release of large ( 1000 gal) quantities of nonyl phenol into Canagagigue Creek on several occasions during the field season. This material, which now appears to have entered the stream from the chemical plant, was present at concentrations well above the LD<sub>50</sub> for all aquatic organisms that have been tested. The result has been a severe disruption in the Canagagigue benthic community downstream of Elmira. A report on these incidents has been prepared at the request of the Ontario Ministry of the Environment, who are evaluating what action is now to be taken. The studies of uptake of chlorophenols by benthic biota were severely affected by this pollution. Nevertheless, several aspects of these studies have proceeded. Six leech species were analyzed for chlorophenols and significant differences were found in the levels of these contaminants accumulated by each species. In addition, several fish species were obtained from Canagagigue Creek downstream of Elmira, and these were dissected into individual organs and analyzed. The results reveal that chlorophenols accumulate in different fish organs than neutral organochlorines such as lindane.

With regard to the identity of the acidic series of products found in Canagagigue in 1980, they have now been identified and their routes of formation elucidated. These products have the general structure:



where R is an octyl or nonyl group and  $n = 1-3$ . They arise from degradation of the appropriate alkyl phenol polyethoxylate surfactant



where  $n = 8-30$ .

These substances are widely used as industrial detergents and as surfactants in the chemical industry. The route of formation of these compounds has been tentatively confirmed in some preliminary experiments.

Finally, with regard to the photolysis of TFM in Oakville Creek, this study was not carried out totally as planned due to the last-minute cancellation of the Oakville Creek treatment by the Sea Lamprey Control Centre. Part of the study was switched to Lynde Creek and the predicted photoproducts were in fact found under field conditions. Research is continuing on this topic.

## INORGANICS SECTION

The objective of this Section is to determine the fate of inorganic contaminants in aquatic ecosystems. Laboratory studies on properties and transformation of various organometallics such as organo-lead and organotin compounds are correlated with field measurements at likely polluted areas in Canada. Other research studies investigate the distribution, pathways, and bioavailability of metals in large river-lake systems. The geochemical controls of lake acidification and the response of drainage basins to airborne deposition of metals are studied in a calibrated watershed.

### Trace Metal Bioavailability

Current models or concepts of the roles of trace metals in vivo indicate that nutritive and toxic effects and assimilability all depend on the chemical form and availability of the metals. From the perspective of availability, the determination of metals in a dissolved state or those metal forms which can be readily desorbed or solubilized from particulate matter are clearly important factors in assessing the impact and degree of hazard of metals in the environment. In addition,

data on metal concentrations in the water column provide information on actual environmental exposure of biotic systems, including man.

This study, in part, addresses the problem of the disposal of dredged spoil and other contaminated solid wastes, e.g., mine tailings and sludges. For Canadian ports, it was estimated in 1980 that  $2 \times 10^6 \text{ m}^3 \text{ yr}^{-1}$  of sediments were dredged with attendant multi-million dollar disposal costs. The approach to predicting possible scenarios for the metals contained in such materials involves the use of a sequential chemical extraction procedure which has been applied to a wide range of environmental sample types (Tables 2 to 4).

Synergistic and antagonistic interactions exert an important influence on the toxicological effects at sub-lethal concentrations of the mixtures of metals present in the environment. Hence, this study has not emphasized the behaviour and transformations of any one element. Thus, the suite of metals investigated so far include Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn and the non-metal, P. This range is being extended to the determination of Ag, As, Be, Hg, Mo, Se and V.

Because colloidal metal forms may comprise the major fraction of what is conventionally regarded as dissolved metal ions, we have also studied the particulate phases and their particle size associations. Although there is considerable interest here and elsewhere in chemical speciation, little emphasis has been given to determinations of the molecular nature of metal complexes in solution. Such work, though important to furthering our understanding of trace metal pathways, may produce confusion at a higher level as it were, because of the very low levels of dissolved metals present in natural waters (Table 1) and the difficulty of obtaining precise and accurate concentration data. In addressing this problem, work is being done using electrothermal atomization atomic absorption spectrometry for ultra-trace analyses and to delineate the sources of interferences which are commonly encountered with this technique.

Another aspect of the study has been the development of a chemical procedure which may be used to model the availability of dissolved metal forms to phytoplankton. We have evaluated differential pulse polarography as a means of distinguishing and quantitating labile and inert metal forms. This work is intended to further our understanding of the ameliorating effects of dissolved organic matter and colloidal material on metal ion toxicity.

In a study of the partitioning of trace metals in Lake Erie, it was found that the average amounts of Al, Cd, Co, Cu, Fe, Mn, Ni, Pb and Zn in dissolved forms were 6, 79, 93, 71, 4, 43, 89, 68 and 81% of the respective total metal concentrations. The analysis of particulate metals from the Lake showed that Cd, Co, Cu, Pb and Zn are generally associated with particles smaller than  $8 \mu\text{m}$ , whereas Fe, and to a lesser extent Al and Mn, occur appreciably with particles larger than  $8 \mu\text{m}$ .



Meltwater and sediment from the Rhône Glacier were similarly studied. Greater than 80% of the total Cd, Cu, Mn, Ni and Zn were found to be in operationally-defined ( $0.4\ \mu\text{m}$ ) dissolved forms. Fe and Al in the meltwater are primarily associated with particles in the size range  $0.4$  to  $8\ \mu\text{m}$ , while Cd, Cu, Mn, Ni and Zn occur with particles smaller than  $0.1\ \mu\text{m}$ . For the sediment, Cu, Ni and Pb were significantly (14, 38 and 52%) present as readily-exchangeable forms.

The sequential chemical extraction procedure adopted for this study has been shown to yield valuable information on the availability of trace metals (see Tables 2 and 3) in environmental samples. The readily-exchangeable metal forms distinguished by this procedure can be considered to arise from inputs of salt-laden water during the spring run-off period as a consequence of road-salting during winter. The metal ions in this fraction are then available to the biotic community at a very sensitive stage in the life cycle of many organisms.

The carbonate and surface-oxide bound forms can be regarded as arising from inadvertent inputs of acidic effluent in areas adjacent to industries or from the melting of acid-laden snow and acid precipitation. In Tables 2 and 3, the percent available column reflects the sum of these two fractions which are operationally defined by the extraction procedure.

The procedure also distinguishes elemental forms associated with Fe and Mn-oxides and bound to organic matter and sulphides. The latter forms may become available as a result of microbial decomposition of organic matter or as a result of the oxidation of sulfidic sediments dredged and dumped in an oxic environment, thus leading to the production of acid seepage. In the case of elemental forms bound to Fe and Mn oxides, they may become available under anoxic conditions. Such conditions are in most cases temporary and hence re-sorption of released elements may be expected once mixing with oxygenated water occurs.

As a result of the growing awareness that the common use of slowly responding analog recorders can lead to serious errors in data interpretation, a microcomputer has been interfaced to a Zeeman Effect Atomic Absorption Spectrometer. We have been able to develop a data acquisition system which has an effective response time of better than 20 ms which offers the following features: 1) the use of electrodeless discharge lamps, 2) simultaneous temperature and absorption recording, and 3) hard copy using an X-Y recorder and calculation of integrated absorption and background only absorption. We are presently using the system to resolve the transient signals (which may be as short as 0.05 s) produced in the graphite furnace in order to understand atomization processes and aid in the selection of optimum experimental conditions and the detection and removal of matrix interferences.

Table 4 summarizes the results on the determination of labile and inert complex forms of Pb, Cd and Zn in the carbonate/surface-oxide bound forms for some selected samples.

**TABLE 1. Dissolved Metals in Nearshore Areas of the Great Lakes.**  
Units in  $\mu\text{g l}^{-1}$ .

	Cd	Cr	Cu	Pb
Lake Ontario	0.04	0.40	1.1	0.14
Hamilton Harbour	0.14	0.66	1.9	3.0
Collingwood Harbour	0.11	0.22	0.65	1.0
Oshawa Second Marsh	0.35	0.60	2.5	1.0
Leslie St. Spit/Aquatic Park	0.18	0.40	4.8	1.3

**TABLE 2. Potential Availability of Metals in Suspended and Bottom Sediments.** Units in  $\mu\text{g g}^{-1}$ . nd = none detected.

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Average Background	0.4	11	25	9	15	10	44
Lake Ontario	2.5	22	155	66	79	190	290
% Available	nd	nd	nd	6	15	10	10
Hamilton Harbour	16	18	265	140	110	365	1970
% Available	37	26	2	19	28	11	19
Oshawa Second Marsh	2.4	19	120	45	108	89	143
% Available	nd	nd	nd	2	3	2	1
Niagara River	3.9	22	113	38	48	82	260
% Available	26	1.6	0.2	6	11	20	7
Collingwood Harbour	1.4	17	93	100	89	170	170
% Available	nd	10	4	3	4	4	8
Leslie St. Spit/ Aquatic Park	2.7	30	104	100	73	480	455
% Available	nd	nd	1	1	4	nd	nd

**TABLE 3. Potential Availability of Metals in Environmental Samples. Units in  $\mu\text{g g}^{-1}$ . nd = none detected.**

	Cd	Co	Cr	Cu	Ni	Pb	Zn
Urban Particulate Matter	75	17.6	403	609	82	6550	4760
% Water Soluble	10	nd	0.7	16	22	0.7	37
% Readily Available	73	20	1.3	30	36	46	67
Incinerated Sludge Ash	9	100	5200	2500	640	1640	14000
% Available	nd	nd	0.05	nd	0.1	0.1	0.1
Podzolic Soil (B)	0.2	13	16	7	12	21	124
% Available	nd	nd	nd	15	18	2	nd
Chernozemic Soil (A)	0.4	15	61	22	26	16	94
% Available	nd	nd	nd	7	3	6	nd

**TABLE 4. Determination of Labile and Inert Complex Forms of Cd, Pb and Zn Extracted from Suspended and Bottom Sediments. Units in  $\text{mg l}^{-1}$ .**

Sample	Cd		Pb		Zn	
	Labile	Inert	Labile	Inert	Labile	Inert
Stn 2:2 m Hamilton Harbour	nd	0.090	0.060	0.056	1.00	1.33
Stn 4:2 m Hamilton Harbour	nd	0.007	0.118	0.054	1.03	0.03
Niagara River	nd	nd	nd	nd	0.16	nd
Collingwood Harbour	nd	nd	nd	nd	0.09	2.0
Leslie St. Spit	0.03	nd	nd	0.05	0.13	0.19

#### **Acid Rain in Turkey Lakes Watershed**

Within the general Departmental objective to "develop a clear understanding of the occurrences and effects of long-range transport of air pollutants (LRTAP) within Canada, ECS has established a goal of studying "selected ecosystems to quantify pathways and to define cause-effect relationships from which predictive models of ecosystem effect can be developed and verified." The Turkey Lakes Watershed (TLW), Algoma, Ontario, is one of the "selected ecosystems." The 1050 ha watershed, located in acid-sensitive shield terrain, is composed



of a staircase of five lake basins, and experiences moderate acid deposition (precipitation pH  $\approx 4.5$ ). The hydrogeochemical response of the watershed to this acid input is being evaluated using a mass balance approach in an effort to determine the geochemical mechanisms and/or interactions controlling the relationship. The TLW is one of five calibrated basins under study by various federal and provincial organizations in eastern Canada. Information from all of these basin studies will be required to completely address the above objectives.

Hydrological and chemical monitoring of the inputs and outputs of the five component lake basins within the TLW was performed throughout the year. This involved continuous measurement of precipitation quantity and stream flow (five stations), daily monitoring of atmospheric deposition, and weekly to bi-weekly chemical sampling of stream, lake, and groundwaters. During periods of high flow such as spring melt, sampling frequency was increased to allow better resolution in the data.

The data generated within this study are being stored in the computerized NAQUADAT data bank. Mean major ion concentrations at the five major stream gauging stations are given in the Table below. Stream station S1 is located just below the headwater lake and each subsequent station is correspondingly lower until S5, which is at the exit of the overall basin.

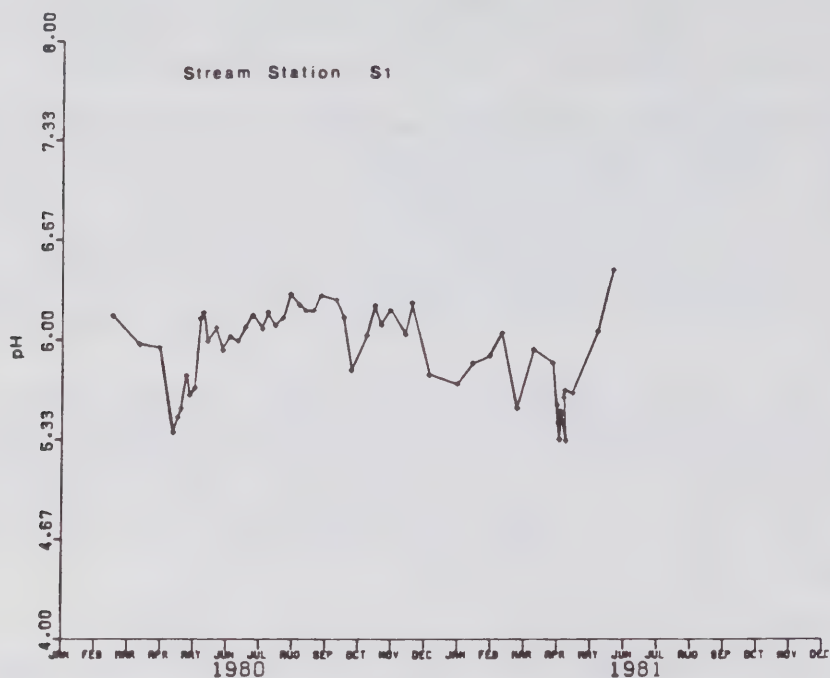
**Mean pH and Major Ion Concentrations ( $\text{meq L}^{-1}$ ) at Stream Stations in the Turkey Lake Watershed (January 1980 to May 1981)**

Station	pH	$\text{Ca}^{2+}$	$\text{Mg}^{2+}$	$\text{Na}^+$	$\text{K}^+$	$\text{SO}_4^{2-}$	$\text{HCO}_3^-$	$\text{Cl}^-$	$\text{NO}_3^-$
S1	5.9	0.15	0.04	0.02	0.01	0.13	0.04	0.01	0.04
S2	6.3	0.19	0.04	0.02	0.01	0.13	0.08	0.01	0.03
S3	6.4	0.22	0.04	0.02	0.01	0.13	0.14	0.01	0.03
S4	6.6	0.26	0.04	0.02	0.01	0.13	0.19	0.01	0.03
S5	6.6	0.27	0.04	0.03	0.01	0.14	0.19	0.01	0.03

The data show that there is an increase in pH,  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  from the headwaters to the exit of the watershed. The headwaters are of the  $\text{Ca}^{2+}$ - $\text{SO}_4^{2-}$  type, while the waters further down are of the more "normal"  $\text{Ca}^{2+}$ - $\text{HCO}_3^-$  type, suggesting that sulphuric acid is the more important weathering agent (compared to  $\text{H}_2\text{CO}_3$ ) in the upper reaches of the TLW, where soil-precipitation interactions are minimized. Monitoring activities will continue throughout the next year.

In addition to the gradients in "average" composition found in the TLW, considerable temporal variation in stream composition have also been observed. The Figure illustrates the degree of variability

observed for pH at S1. Note the distinct pH depressions occurring during spring melt. Similar pH depressions have been observed elsewhere in Ontario. Further quantification of the magnitude and extent of this short-term acidification are being addressed by intensive snowpack, stream and lake sampling programs throughout late winter and spring of 1982.



Seasonal dependence of pH at S1 in the Turkey Lakes Watershed.

### Methylation of Heavy Metals

Metals in the aquatic environment are subject to biotic and abiotic reactions resulting in the formation of organometals and organo-metalloids with different toxicological behaviour and bioaccumulation characteristics. Such transformation also has environmental consequences in mobilization of the element from sediment, and transmethylation of other elements. Identification of the chemical forms of an element is of prime importance and will be of significance to the program under the Great Lakes Water Quality Agreements, annexes 7, 11 and 12. Organotin and organolead compounds are of high priority under the Environmental Contaminants Act. The observations of alkyllead and alkyltin compounds in environmental samples indicate a great need to investigate the transformation mechanisms of these elements and also the forms of lead and tin in the environment.

An important area of environmental studies is the development of analytical techniques for chemical speciation. The combination of chromatography and an element-specific detection will provide a powerful system for the identification and analysis of both volatile and non-volatile organometals in the sample.

Laboratory experimentation established the fact that tetraalkyllead compounds can be accumulated by fish with the highest concentration in the lipid tissue. A survey of the occurrence of alkyllead compounds in fish, sediment, aquatic plants and water in high lead areas was carried out. Only fish were found to contain tetraalkyllead.

An environmental survey of the occurrence of trialkyllead species ( $\text{Me}_3\text{Pb}^+$ ,  $\text{Et}_3\text{Pb}^+$ ) has confirmed that  $\text{Et}_3\text{Pb}^+$  can be formed in fish containing  $\text{Et}_4\text{Pb}$ . This finding would have significant bearing on the toxic effects of tetraalkyllead in fish because the  $\text{Et}_3\text{Pb}^+$  species has been known to be responsible for  $\text{Et}_4\text{Pb}$  toxicity in mammals.

The role of metals in catalyzing the formation of  $\text{MePb}$  in the  $\text{Pb(II)} + \text{MeI}$  system was studied after the finding that  $\text{Pb(II)}$  could be methylated by  $\text{MeI}$ . It was found that electropositive metals ( $\text{Al}$ ,  $\text{Mg}$ ,  $\text{Zn}$ ) reduced  $\text{Pb(II)}$  species to  $\text{Pb}$  metal available for reaction with  $\text{MeI}$  to form  $\text{MePb}$ .

The study of the effect of pH on the methylation of  $\text{Pb}$ ,  $\text{Hg}$ ,  $\text{As}$  and  $\text{Se}$  showed that pH affected the methylation of different elements in lake sediments. The formation of tetramethyllead from trimethyllead acetate increased with increasing pH and proceeded through both biological and chemical mechanisms. Methylmercury was formed from inorganic mercuric chloride only in the pH range 5.5 to 6.5. Dimethylmercury was not detected. Arsenic methylation was enhanced below pH 5.5, but occurred over the pH range of 3.5 to 7.5. The levels of methylated  $\text{Se}$  compounds were low at pH 3.5 and, generally, increasing pH favoured the methylation of  $\text{Se}$ .

Both  $\text{Sn(II)}$  and  $\text{Sn(IV)}$  salts can be methylated to  $\text{MeSn}^{3+}$ ,  $\text{Me}_2\text{Sn}^{2+}$ ,  $\text{Me}_3\text{Sn}^+$  compounds in lake sediment. A comparative toxicity study with various organotin compounds on freshwater algae showed that toxicity is related to length of the carbon chain, degree of alkyl substitution and also to the oxidation number of tin, with the trialkyltin being the most toxic form.

The results of two field trips to various lakes, rivers, harbours and marinas in Ontario to survey the environmental occurrence of methyltin compounds showed that there were significant amounts of methyltins in water. Whether these are the result of degradation of other organotins or methylation products of inorganic tin remains to be investigated. These findings are, however, significant. This is the first report on the occurrence of methyltin species in Canadian waters (see Table 1).

A contract study "Effects of acid water on leaching of metals from domestic water supplies" was completed by Barringer Co. The contract involved a laboratory study of the effect of pH, temperature, and hardness on the leaching of metals from three types of domestic plumbing materials, namely, lead, copper and galvanized pipes under static and dynamic conditions. Major findings are: decreasing pH increased the rates of leaching of  $\text{Pb}$ ,  $\text{Cu}$  and  $\text{Zn}$ . A decrease of pH from



eight to six resulted in substantial increase of leaching of Pb and Cu from the most widely-used copper pipes. Dramatic effects of metal leaching from all types of pipes were observed in static tests of varying pH and hardness for 2-hr, 12-hr, 10-d periods over that of dynamic tests. A survey of 105 homes and apartments in Toronto areas substantiated much of the findings of the laboratory studies. The first-drawn water always contained more metals than that after 5-minute running. Only Pb was found at concentrations higher than the recommended level (50 ppb) at some sites in the static samples.

**TABLE 1. Concentrations ( $\mu\text{g/L}$ ) of Methyltin Species in Unfiltered Subsurface Water\*.**

Location	$\text{Me}_3\text{Sn}^+$	$\text{Me}_2\text{Sn}^{2+}$	$\text{MeSn}^{3+}$
Lake Superior (Thunder Bay)	—	0.03	0.15
Lake Superior (Red Rock)	0.5	0.03	0.23
Lake Superior (Marathon)	—	0.03	0.21
Turkey Lake 1	—	0.05	0.24
Turkey Lake 2	—	0.02	0.11
Turkey Lake 3	—	0.05	0.18
Turkey Lake 4	—	0.04	0.20
Turkey Lake 5	—	0.05	0.25
Sault Ste. Marie Harbour	—	0.04	0.25
Ramsey Lake (Sudbury)	—	0.04	0.22
Nepewassi Lake (Sudbury)	—	0.03	0.20
Lake Nipissing (North Bay)	—	0.09	0.23
Plastic Lake	—	0.04	0.17
Collingwood Harbour	—	0.05	0.20
Owen Sound Harbour	—	0.04	0.17
St. Clair River 1	—	0.18	0.64
St. Clair River 2	—	0.21	0.68
Lake St. Clair (Mitchell Bay)	—	0.10	0.35
Lake St. Clair (marina)	—	0.22	0.53
Thames River (400 m upstream from mouth)	—	0.21	0.67
Port Dover Harbour	—	0.16	0.61
Grand River (mouth)	—	0.14	0.37
Hamilton Harbour	—	—	0.06
Toronto Harbour	—	0.29	0.96
Whitby Harbour	—	0.28	1.20
Belleville Harbour	—	0.24	0.92
Kingston Harbour	—	0.40	1.22
St. Lawrence River 1	—	0.03	0.28

\* Minimum detectable concentration of each species approximately  $0.04 \mu\text{g/L}$ ; for concentrations of Sn(IV) species, see Table 1; precise sampling locations available upon request.

#### Fate of Organotins in Water

Organotins are toxic chemicals which are used extensively as polyvinylchloride heat and light stabilizers, catalysts and biocides.

Little is known of their occurrence in the environment, and, in particular, their aquatic fate. For these reasons, organotin biocides, bis (tri-n-butyltin) oxide (TBTO). The approach is to combine field observations with results from the laboratory on well-defined transformation pathways. Accordingly, this study will determine, under laboratory studies, 1) hydrolysis, 2) photolysis, 3) volatilization, 4) adsorption to sediments and suspended solids, 5) microbial transformation, and 6) accumulation in algae and fish, and, under field studies, 7) preliminary sampling of likely polluted sites to determine the presence of a particular pollutant in such "compartments" as water, sediment, algae and fish, and 8) based on (7), selection of a specific site at which to conduct a detailed investigation of the persistence and fate of butyltins.

The goal of this study is to determine the persistence and fate in aquatic ecosystems of a representative organotin biocide, bis (tri-n-butyltin) oxide (TBTO). The approach is to combine field observations with results from the laboratory on well-defined transformation pathways. Accordingly, this study will determine, under laboratory studies, 1) hydrolysis, 2) photolysis, 3) volatilization, 4) adsorption to sediments and suspended solids, 5) microbial transformation, and 6) accumulation in algae and fish, and, under field studies, 7) preliminary sampling of likely polluted sites to determine the presence of a particular pollutant in such "compartments" as water, sediment, algae and fish, and 8) based on (7), selection of a specific site at which to conduct a detailed investigation of the persistence and fate of butyltins.

TBTO does not hydrolyze over a period of two months at 25°C and at pH 3, 7 and 11. An experiment on the volatilization of TBTO from distilled water at room temperature showed that no volatilization occurred over a 62-day period at 22°C. Although there was a possibility of adsorption of TBTO to glass, it is likely that in natural water bodies adsorption to organic matter would be even more pronounced, and that volatilization would not be a significant pathway of environmental distribution. Preliminary experiments on the sunlight photolysis of TBTO indicate little photolytic conversion over a period of 83 days. Laboratory experiments are under way with more intense light sources, so that a definite conclusion may be made on whether TBTO photolyzes (i) directly, or (ii) as a result of photosensitization by naturally-occurring humic material.

A survey was made of butyltins in water at 30 locations in Ontario. Butyltin contamination is widespread; the table below shows the most significant results.

#### Butyltins in Unfiltered Subsurface Water, $\mu\text{g L}^{-1}$ .

Location	$[\text{Bu}_3\text{Sn}^+]$	$[\text{Bu}_2\text{Sn}^{2+}]$	$[\text{BuSn}^{3+}]$	$[\text{Sn}^{4+}]$
Collingwood Harbour	1.0	—	—	50.1
Lake St. Clair (Marina)	2.9	7.3	8.5	6.0
Toronto Harbour	0.8	0.3	—	1.0
Ramsey Lake (Sudbury)	0.7	0.02	—	48.7

This is the first report of butyltins in Canadian waters. The concentrations of tri-n-butyltin in the locations above are 15 to 60% of the  $\text{LC}_{100}$  12-d value for a sensitive aquatic species, rainbow trout yolk sac fry.

The surface microlayer (approximately 60  $\mu\text{m}$  thick as sampled with a glass plate) was also sampled at the same 30 locations. The most notable results were (i) for Nepewassi Lake (Sudbury) and Lake Nipissing (North Bay), in which the amounts of  $\text{Sn}^{4+}$  in the surface microlayer were 38% and 18%, respectively, of the amounts in the whole depth of subsurface water, and (ii) for Whitby and Belleville Harbours, in which the amounts of dibutyltin in the surface microlayer were 30% and 23%, respectively, of the amounts in the whole depth of subsurface water. This finding, whose generality will be determined, may have profound significance for water quality monitoring and surveillance programs.

Work is continuing on adsorption to sediment, bioaccumulation, microbial transformation and occurrence in the Great Lakes Basin.

### **Heavy Metals in the Niagara River and Plume**

The nearshore zone of the Niagara River mouth has been designated by the Great Lakes Water Quality Board in the past as a problem area. A number of industrial discharges to the Buffalo River and to the Upper and Lower Niagara River contribute to the pollution of water and suspended loads of the Niagara River. The 5500  $\text{m}^3/\text{sec}$  discharge of the Niagara River, carrying annually 4.8 million tons of fine-grained sediment into Lake Ontario, has a significant effect on the water and sediment quality of the Western Basin of Lake Ontario, and most likely affects the whole lake. The mercury and PCB distribution in Lake Ontario sediments pinpoint the Niagara River as the major source of input. Suspended sediment is primarily of concern because of its ability to bind contaminants.

Concentration profiles of heavy metals in sediment at the Niagara River mouth showed a small decrease of Cr, Zn, Cu, Ni and Pb and a significant decrease in Hg inputs to Lake Ontario by the river over the last 10 years. However, Hg concentrations in the surficial sediment in the vicinity of the river mouth remain high, up to 7  $\mu\text{g g}^{-1}$  dry weight. The scanning for organic pollutants in the sediment showed about 45 compounds present in the neutral fraction of the extracts in concentrations many times higher than in the Niagara River water. These were identified as polycyclic aromatic hydrocarbons (PAHs), chlorinated aliphatic and aromatic hydrocarbons, and nitrogen and sulfur containing hydrocarbons. The occurrence and composition of the nepheloid layer in the Western Basin of Lake Ontario was studied to investigate the possible transport of contaminants by this layer over the entire Lake Ontario. Next fiscal year the study will continue, including an investigation of the occurrence and nature of organic pollutants and metals in suspended and bottom sediment in the Eastern Basin of Lake Erie and their possible transport via the Niagara River. Concentration of organic pollutants and metals in the nepheloid layer in Lake Ontario will be determined. Investigation will be carried out on effects of sediment-associated pollutants on phytoplankton and zooplankton by using natural plankton population and contaminated sediment from the Niagara River ecosystem.



## Atmospheric Pollution of Aquatic Systems

A major departmental research objective is to "determine the ability and capacity of the ecosystem of Canada to withstand contamination due to the long-range transport of airborne pollutants (LRTAP)." Recognizing the overall complexity of such an endeavour, this study has initially addressed this objective by studying specific ecosystem - acid interactions in calibrated watersheds in Nova Scotia and Ontario. The purpose is to determine the factors controlling the degree and rate of acidification of these drainage basins and associated lakes by measuring the geochemical response of the watersheds to the input of acids. Both watersheds are located in areas considered to be sensitive to excessive atmospheric loading of acid and are part of a network of calibrated systems in Canada and the U.S.A. which are under study to define the effects of LRTAP.

Questions related to the source of acid present in acidifying systems were addressed through measurement of the organic acid contribution to the total acidity of lakes and rivers in Nova Scotia, while the importance of short-term acidification was studied by intensively monitoring the major ion chemistry of the lakes and streams of the Turkey Lakes Watershed (Algoma, Ontario) throughout the spring melt of 1981.

A method was developed to measure the contribution to acidity of organic acids for natural water susceptible to acid precipitation. The organic acids from two natural waters were isolated and studied in detail to quantitate their dissociation behaviour and carboxylic acid content. A simpler fluorescence quenching technique was developed so the organic acids content of samples could be determined directly and the  $H^+$ , supplied by dissociation, easily estimated.

The free  $H^+$  concentration, total  $H^+$  supplied by the dissociation of organic acids, and the total organic carboxylic acid content of several lakes and rivers in Nova Scotia are shown below.

### **Acids in Nova Scotian Surface Waters ( $\mu M L^{-1}$ ).**

Sample	Free $H^+$	Total $H^+$ from Organic Acids	Total Organic Acids
West River	50	73	120
Medway River	16	87	120
Mersey River	32	34	52
Beaverskin Lake	4	21	25
Pebblelogitch Lake	25	110	160
Kejimikujik Lake	5	22	27

Clearly, organic acids are an important source of  $H^+$  for these Nova Scotian waters. Some of the  $H^+$  from organic acids must have been neutralized by reaction with basic species, since the free  $H^+$  is generally lower in concentration.

Data collected during spring runoff in the Turkey Lakes Watershed showed that short-term acidification "events" did occur in 1981.

Maximum variation in  $H^+$  concentration was observed at the stream station below the headwater lake, where  $H^+$  increased  $\sim 3\times$  during a minor melt in late February and  $\sim 5\times$  during the major melt in early April, e.g., pH from 6.0 to 5.3. Variation in  $SO_4^{--}$  and  $NO_3^-$  concentrations were also observed. The near surface waters of the lakes also experienced pH depressions, although these were of a lesser magnitude.

## **RADIONUCLIDES SECTION**

The objective of this Section is to study the behaviour in aquatic ecosystems of both naturally occurring and artificial radionuclides. Studies include the determination of pathways of radionuclides discharge to rivers and lakes during nuclear fuel cycle operations; determination of concentrations of these radionuclides in water, selected biota, and sediments to assess the radiological dose to organisms; the verification of predictive models for the dispersion of radionuclides into ground and surface water; and the measurement of concentration profiles of certain radionuclides in lake sediments to provide a time-scale for determining the lifetimes of other contaminants in aquatic ecosystems.

### **Radioactive Contaminants in the Great Lakes**

Concern over the potential buildup of radionuclides in the Great Lakes, due to the developing nuclear power program along the shoreline, was expressed in the Canada/U.S.A. Water Quality Agreement of 1972. Development of a radiological water quality objective began at that time and was included in its final form in the 1978 Agreement. Annual measurements of radionuclide concentrations in open waters of the Great Lakes which started in 1972 helped in the development of the objective which is that no individual drinking water from the Great Lakes system should receive in a year a dose of more than one millirem.

Annual samples from near the surface and the bottom at each major basin of all lakes have been collected with the cooperation of U.S. Environmental Protection Agency, GLFRB, and the Technical Operations Division of NWRI. Analyses of these samples as well as sediment and fish, for specific radionuclides have enabled radiological dose calculations to be made and determine relative importance of different sources and the resultant pathways of radionuclides to overall trends of radioactivity in the Great Lakes.

Open water samples from all the Great Lakes and fish samples from all but Lake Michigan were obtained in the summer of 1980 and analyses for the radionuclides  $^{90}Sr$ ,  $^{137}Co$  and  $^{125}Sb$  were completed by the summer of 1981. The results of these analyses were included in the

IJC Water Quality Board Annual Report for 1981. The radionuclides measured were apparently all introduced by fallout from nuclear weapons testing, since no evidence was found of radionuclides specifically related to nuclear industry. The radiological doses to individuals drinking water from each lake were calculated to be; Lake Superior, 0.05 mrem; Lake Michigan, 0.10 mrem; Lake Huron, 0.11 mrem; Lake Erie, 0.06 mrem; Lake Ontario 0.13 mrem. All lakes gave similar results as the previous year with the exception of Erie which was 50% lower. Bioaccumulation of  $^{137}\text{Cs}$  in fish showed large differences between species, with rainbow trout at 2600 being much lower than pickerel at 22,200.

Earlier work on a new approach to determine the very low levels of radionuclides in the Great Lakes was finished.

### Radium at Port Granby

An earlier study of the  $^{226}\text{Ra}$ , As and  $\text{NO}_3^-$  levels in Lake Ontario off the Port Granby waste management site of Eldorado Nuclear Ltd. showed that these contaminants were leaving the site, although the two creeks, which historically drained the site, had been dammed. The Atomic Energy Control Board which licenses the site and Eldorado Nuclear Ltd., which owns it, both have need of scientific information on pathways and rates of transfer of radioactive and other contaminants to Lake Ontario.

A study of the groundwater leaching of  $^{226}\text{Ra}$  from the site was undertaken to calibrate the hydrogeologic parameters used in the NWRI two-dimensional contaminant transport model, in order to predict future leaching from the site.

The wastes are buried in sandy soil at the top of the bluffs rising about 30 metres from the narrow beach. A till layer of clay, cobbles and boulders underlies the waste and causes seepage of leachate at the face of the bluffs. The major groundwater flow is through a lower sandy layer to the lake, the water table being about 50 cm below the beach surface at the front of the bluffs. A series of 12 piezometers were jetted into the beach to a depth of two metres between the eastern and western boundaries of the site. Samples of groundwater were taken periodically from the piezometers and the seepage sites and analyzed for  $^{226}\text{Ra}$ . The level of the water table in each piezometer was monitored also during the field season. Analytical results show that the main contamination of the groundwater is occurring at the centre of the site where the seepage is taking place. The seepage  $^{226}\text{Ra}$  concentration was fairly steady during this period, averaging about 13 pCi/L but the nearest piezometer showed a decline from 50 pCi/L to about 10 pCi/L.

A contractor was brought in at the end of the field season to drill two deep holes to bedrock and install piezometers, sealed with bentonite, at three depths. Hydraulic characteristics and  $^{226}\text{Ra}$  levels will be determined at these depths when the beach is free of ice.



## Aquatic Pathways of Radionuclides

In assessing the environmental impact of nuclear power development it is necessary to understand the behaviour of radionuclides released to the environment. Pathways of naturally-occurring radionuclides such as  $^{210}\text{Pb}$  and other decay products of uranium and thorium and fallout radionuclides, such as  $^{137}\text{Cs}$ , can be studied in the natural environment and related to the behaviour of radionuclides discharged during operation of the nuclear fuel cycle. The transfer of  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  from the atmosphere through the water column and sediments of Lake Huron has been a technique for measuring sedimentation rates, and age profiles of sediments has been developed. These age profiles can be used, along with other contaminant analyses of the sediments, to determine the time that these contaminants were first introduced into the aquatic ecosystem.

Age profiles of sediment cores from 12 lakes in northern and eastern Ontario were determined in a cooperative study with Fisheries and Oceans Canada to determine historical inputs of heavy metals to these lakes. Similarly,  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  profiles of cores from Oshawa Second Marsh were measured to determine sediment accumulation rates and predict future water levels in the marsh. A reassessment of  $^{210}\text{Pb}$  and  $^{137}\text{Cs}$  data from three cores from Nipigon Bay, Lake Superior showed that toxic dehydroabietic acid discharged from a nearby pulp mill degraded very slowly in the sediments compared with the water column.

Sediment accumulation rates are currently being measured in cores taken in Lake Ontario about 1 km off the mouth of the Niagara River in order to determine the history of several contaminants known to be present in the river. Three cores taken from supposedly similar locations have given sedimentation rates of 1.3, 0.8 and 0.6 cm per year. Since the rates appear to change rapidly over short distances it is important that the other contaminants studied are analyzed in the same core used for age profiling. The possible introduction of transuranium elements into the Niagara River from a shut-down fuel reprocessing plant at West Valley, New York, via Cattaraugus Creek and Lake Erie, is being studied. A separation technique for Pu, Am, U and Th using isotopic tracers is being developed.

**ANALYTICAL METHODS DIVISION**





The Analytical Methods Division (AMD) is responsible for research and development of methodologies for chemical and microbiological pollutants in the aquatic environment, for conducting national and international quality assurance programs and for providing centralized computing service to all components of CCIW. The Division undertakes national and regional research programs in analytical chemistry, microbiology and quality assurance and transfers completed technology to regional laboratories of IWD and other clients. The objectives of the Division are to:

- develop new and improved analytical methods and sampling procedures which are accurate, cost-effective, sensitive and unambiguous for the identification and quantification of contaminants in the aquatic ecosystem;
- play the lead role in documentation, validation and standardization of analytical methodologies and implementing quality assurance and control programs for ensuring accuracy, comparability and reliability of analytical data;
- provide a service requiring the use of sophisticated instrumentation and facilities such as gas chromatography - mass spectrometry, Clean and Hazardous Chemicals Laboratory (CHCL);
- evaluate microbiological techniques for the assessment of mutagenic and toxic properties of waters and effluents;
- develop, assess and field-evaluate more sensitive and reliable sampling and analysis techniques for bacterial, fungal, viral and biochemical indicators in natural waters, wastewaters and sediments;
- develop realistic microbiological water quality criteria for the protection of public safety; and
- provide centralized computing, plotting and key-punching service to all components of CCIW.

The staff of the Division maintains close contact with scientists in other Canadian federal departments, provincial governments, U.S. federal and state agencies, and with universities. In some cases collaborative studies are undertaken. The Division strongly supports the work of the International Joint Commission, the International Standards Organization, American Society for Testing and Materials, Federal Interdepartmental Committee on Pesticides, and Association of Official Analytical Chemists, by membership on committees and task groups.

The Analytical Chemistry Research Section concentrates on the development of new techniques and the improvement of existing techniques

or the sampling, separation, identification, and quantification of chemical constituents of water, sediment and biological material. Techniques frequently used include high pressure liquid chromatography, gas chromatography, gas chromatography-mass spectrometry, electrochemical techniques and spectroscopy.

The Quality Assurance and Methods Section is responsible for establishing quality assurance control programs to monitor laboratory performance to ensure that data generated are valid and compatible on a regional, interagency, interdepartmental, national and international basis. In addition, other important activities include the development of standard reference materials (water, sediment, and biota samples) for chemical and biochemical parameters, and the generation of interlaboratory specifications for precision, accuracy and detection limits. The Section is also responsible for adapting, evaluating and developing suitable chemical methodologies, and for advice on solving analytical problems encountered in the regional laboratories.

The Microbiology Laboratories Section has two main program areas. One is to develop and evaluate microbiological methodologies and criteria for monitoring, assessing and maintaining water quality from the standpoint of chemical contaminants and microbiological hazards. The other is the environmental research on the effects of pollutants on the population of microorganisms in the aquatic ecosystem.

The Computer Services Section is responsible for providing centralized computing facilities to all groups within CCIW. The Section is essentially service oriented. It is responsible for the operation and maintenance of the CYBER 171 computer on a daily basis, for planning and evaluating the future needs of the Centre and for ensuring that adequate systems are available when needed.

The CHCL laboratory is used primarily for methods development research involving trace contaminants requiring special, ultraclean working environment and highly sensitive instrumentation. In addition, the laboratory will prepare standards of hazardous compounds and other ultra-pure standards for government service laboratories and will participate in quality control programs.

#### **ANALYTICAL CHEMISTRY RESEARCH SECTION**

The Analytical Chemistry Research Section is engaged in advanced methodology and instrumentation research. The main objective is to provide improved methods to IWD regional laboratories and other agencies within the federal government. The techniques currently employed include atomic and molecular spectroscopy, electroanalytical techniques, high resolution gas chromatography, GC/MS, high pressure liquid chromatography and radioimmunoassay. Analytical methods are developed for water, sediment, soil, fish, aquatic plant materials, waste waters, solid wastes, road runoffs, leachates, etc. The sensitivity of the methods developed within ACRS vary depending upon the

need of the end user and sample matrix. In the majority of cases the detection limits are in low parts per trillion to sub-parts per billion range.

The following is a brief summary of the activities of ACRS during 1981.

### ICAP

Methods for the determination of trace metals in environmental samples using atomic emission spectroscopy with inductively coupled argon plasma (ICAP) excitation have been developed to the point where routine determination of 12 trace metals, Al, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, V, Zn, can be carried out at sub  $\mu\text{g L}^{-1}$  levels. In the procedure used for water analysis, the major ions Ca, Mg, Na, K, Ba, and Sr can be determined simultaneously. A method for determining As and Se in environmental samples has also been developed. Both of these technologies have been transferred to the Water Quality Branch for future use.

### Electrochemical

A new technique for high-speed measurement of dissolved oxygen, conductance and temperature has been developed for "in situ" profiling of a water body. A test apparatus employing a flow cell and various sensors was evaluated in the laboratory to establish the speed of measurement, linear range and response time. Satisfactory operation was achieved up to a maximum profiling speed of 5 m/sec. No interfering effects were observed from surfactants and sulfide. An immersible microprocessor-based digital system suitable for in situ operation is being designed for field testing.

A new selective ion electrode based on  $\text{Ag}_2[\text{HgI}_4]\text{-Ag}_2\text{S}$  was developed which was found to be superior to existing selective ion electrodes employing  $\text{Ag}_2[\text{HgI}_4]$ . The electrode was tested using  $\text{Ag}^+$ ,  $\text{Hg}^+$ ,  $\text{Hg}^{2+}$ ,  $\text{I}^-$  and cyanide ions to establish performance characteristics (potential activity graphs, stability, precision, response time, effect of pH and redox potential).

A reference electrode system utilizing the cation exchange properties of perfluorosulfonic polymer membranes (Nafion) has also been developed. Conventional electrodes respond to anions and frequently contamination of the sample by the electrolyte interferes with the measurement. With the cationic membrane the determinant of the electrode potential are the concentrations of the cations in the inner and outer compartments (Figure 1). Hence the kind and concentration of anions have no effect on the measured potential. By varying the cationic form of the membrane and by selecting appropriate compositions of the filling solutions, a variety of ion selective electrodes can be prepared.



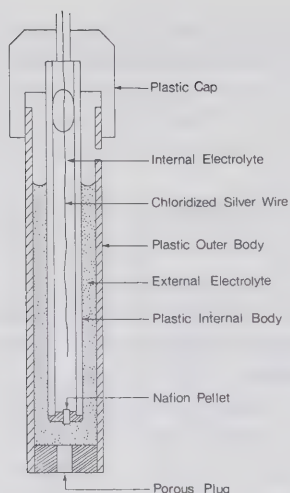


Figure 1. Structure of Reference Electrode

A potentiometric method for the determination of organohalides in natural water has been developed. It involves adsorption of organohalides from water samples onto porous polymer Tenax GC followed by thermal desorption at 400°C and oxidative combustion to hydrogen halides. The halides are captured in an aqueous solution of formaldehyde and sulfamic acid and measured either by direct potentiometry with a high sensitive chloride electrode or by potentiometric titration with  $\text{Hg}^{2+}$  titrant. The efficiencies of the adsorption combustion and detection have been studied and a procedure for the elimination of interferences developed. Analysis time is rapid (2 minutes) and procedures are simple, making the technique suitable for routine application. The method is being evaluated by Water Quality Branch.

### GC and GC/MS

Three methods of extraction were evaluated for the quantitative determination of chlorinated benzenes in bottom sediments. Recoveries of chlorinated benzene isomers at three different levels from two different types of sediment were determined using traditional Soxhlet extraction, ultrasonic extraction followed by centrifugation and steam distillation techniques. Although all three methods are quantitative, the steam distillation method was found to be the most efficient for determination of chlorinated benzenes in bottom sediments, in terms of time and simplicity.

### HPLC

Analytical potential of voltammetry as a sensitive and selective detector for HPLC was investigated. Electrochemical characteristics of various organic contaminants, using both cathodic and anodic ranges, were optimized. These included phenols, amines, carbamates, nitrocompounds and organo-metallics. The HPLC-voltammetric detection

system was applied to determine various carbamates and decomposition products of TFM in natural waters.

An automated multi-wavelength scanner (Fig. 2) was developed in cooperation with Engineering Services and was interfaced with an HPLC-fluorescence system in order to provide confirmation and quantitation of various polynuclear aromatic hydrocarbons (PAH) and carbamates. The above system was found to provide the same degree of confirmatory capability as HGC/LRMS system on selected PAHs and Baygon. The AMI Scanner has been expanded to include 25 wavelength changes in a single run. Additional features are also incorporated which will enable the scanner to record excitation, emission and synchronous spectrofluorescence spectra. The system is presently being tested using various PAHs.

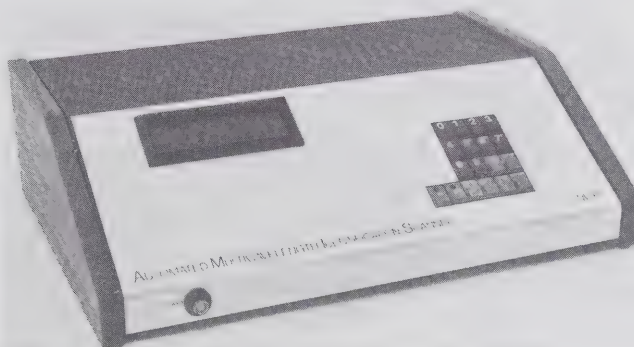


Figure 2. Automated Multiwavelength identification scan.

### The Niagara River

Quantitative analysis of organic contaminants in the Niagara River water by high resolution WCOT column gas chromatography with selective mass spectrometric detection was carried out. The presence of persistent toxic substances in the Niagara River indicated that more than 197 organic micropollutants were detected by GC/MS. These compounds may be divided into the following categories:

1	Neutral Fraction	Chlorinated benzenes PCBs Aliphatic hydrocarbons Aromatic hydrocarbons Polynuclear aromatic hydrocarbons
2	Acidic Fraction	Organic fatty acids Alcohols/phenols Aldehydes/ketones Ethers Phthalates
3	Basic Fraction	Pyridines Anilines Diamines Phthalates

## Specialized Service and Technology Transfer

Niagara River suspended sediments were analyzed, in cooperation with WQB Ontario Region, for priority organic pollutants using high resolution GC/FID and GC/MS. A Varian Matt 311 A mass spectrometer interfaced with a Varian 2700 gas chromatograph was employed. Full scan mass spectral data and reconstructed ion chromatogram indicated the presence of the following compounds in the suspended sediments: Alkyl benzenes, polynuclear aromatic hydrocarbons (PAH), alkylated PAHs, chlorobenzenes, PCBs and phthalates. An Environmental Protection Agency--base/neutral standard was used to establish relative retention time of individual compounds.

A high resolution GC/High resolution MS was also used on a number of fish extracts from the Great Lakes Basin to confirm the presence of 2,3,7,8-Tetrachlordibenzo-p-dioxin. The initial screening and quantitation was performed by WQB.

Methods for determination of PAH and carbamates were successfully transferred to WQB regional laboratories in Burlington and Calgary. Assistance was also provided to WQB analytical services laboratory in validating their data on baygon samples from the Winnipeg area. The Baygon method based on HPLC-fluorescence-AMI scanner was used for analysis and confirmation. Methods for determination of PAH and carbamates have been submitted for inclusion in IWD Analytical Methods Manual.

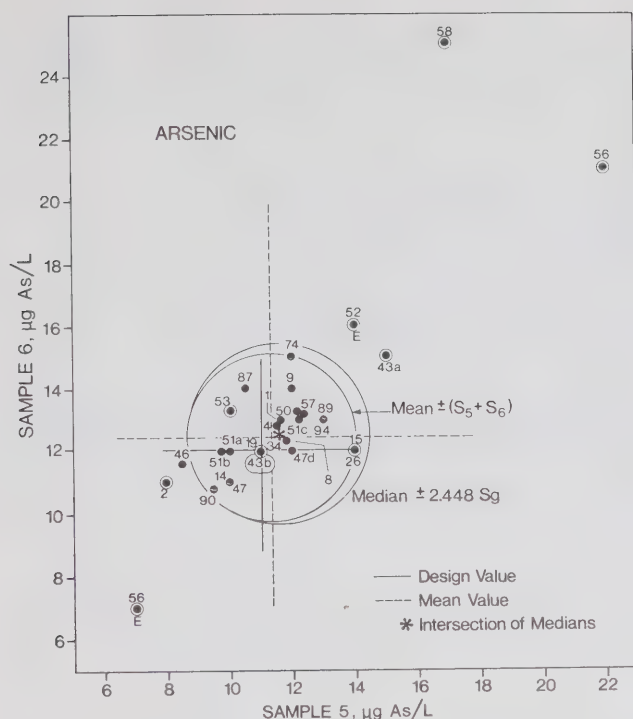
A number of methods developed within ACRS have been accepted or are in the process of being accepted as standard test methods by ASTM and International Standards Organization.

## QUALITY ASSURANCE AND METHODS SECTION

The work of the Section comprises three main areas: quality assurance; development of certified reference materials (CRMs) and reference materials (RMs); and methods development. The quality assurance program involves the design and implementation of several types of quality control (QC) studies as well as investigations of sample homogeneity and stability. These programs assess the analytical performance and ensure the generation of reliable, valid and compatible analytical data on a regional, national and international basis. Development of CRMs and RMs (Fig. 3) are essential to increase the effectiveness of these quality control studies. Reference materials and CRMs are also required for methodology development, for the evaluation of precision and accuracy of laboratory data and for QC studies for the selection of contract laboratories.

The methods development program involves applied research to develop or validate analytical methods for water, sediments and biota. The Section also provides advice and solutions to analytical problems encountered in the regional laboratories of the WQB.





Paired sample plot for Samples 5 and 6

- Hydride generation technique
- ⊙ other than hydride general techniques

Figure 3. An example of a Youlden plot from a quality control report.

### Quality Assurance

#### a) Interregional Quality Control Studies.

As an on-going activity, 12 studies involving natural water and some sediment samples were conducted for the analysis of a wide range of inorganic parameters and PCBs routinely determined in Water Quality Branch laboratories. These studies involved all five regional WQB laboratories.

#### b) Special QC Studies.

Two special studies were conducted during 1981, to investigate specific problems with aluminum analysis and to compare methodology for alkalinity determination. Upon urgent request of the WQB (Pacific Region) two special QC studies for fenitrothion were designed and are currently in progress.

#### c) National QC Studies.

National QC studies involve over 100 federal, provincial, university and private laboratories and cover both organic and inorganic parameters. These studies serve to assess methodology and data of the WQB laboratories by comparison with peer laboratories, to establish laboratory performance of both WQB and other laboratories, permit selection of private

laboratories for contract analyses and provide additional data for RMs and their certification. Two studies (PCBs and major ions) were designed and initiated during the year.

d) International and Interdepartmental QC Studies.

The Section has provided a lead role in the quality assurance for the International Joint Commission's Great Lakes International Surveillance Program. Four international studies were designed, prepared and distributed. These studies included arsenic and selenium, major ions, trace metals and total phosphorus in water. In total, over 100 lab-specific performance reports were prepared and provided for the International participants and analysts. Figure 3 shows an example of data presentation taken from a quality control report.

Under the auspices of the Federal Interdepartmental Committee on Pesticides, the Section acts as the coordinator for the water and sediment check sample program in Canada. A study on PCB analysis was again initiated because of the overall unsatisfactory laboratory performance in the past study. In addition to the usual water laboratories, other laboratories such as wildlife, fish, forest and food were requested to participate. Section personnel have also been involved in collaborative studies for standardization of analytical methods through the Association of Official Analytical Chemists and the American Society for Testing and Materials.

e) Specification Study.

Analytical methods used in the Water Quality Branch laboratories currently have performance statistics based on data obtained at one concentration by a single operator. Since our data are obtained from several laboratories, it is essential to obtain interlaboratory performance statistics for real test samples at several concentrations in order that the data stored in the National Water Quality Data Repository (NAQUADAT) be more meaningful and useful to present and future users.

A technical report on the first phase of this study was finished this year providing specification statements at three concentration levels on 53 analytical methods in the IWD analytical methods manual (trace metals, major ions, nutrients and physical parameters). As an on-going program, phase II is already underway for metals and major ions at additional concentration levels.

f) Sample Stability and Preservation Studies.

A prerequisite of quality control studies is the verification of sample integrity from the initial sample preparation to the final analysis. Although many parameters have

been analyzed routinely for many years, both quality control studies and stability data are lacking. Long-term stability studies (4 to 5 years) on PCBs in lake sediment and major ions and trace metals in water are continuing and short-term stability studies (up to one year) on organochlorines in water and in sediment have been initiated. The results will also provide valuable information for the collection, preservation and storage of samples for future surveillance programs. An investigation of water and sediment sample storage conditions for organochlorine pesticides was also initiated.

### **Certified Reference Materials and Reference Materials**

Several sediment reference materials were prepared by the Section for use in methodology standardization, calibration, quality control studies and for evaluation of contract laboratories. Two lake sediment reference materials for arsenic, selenium are at their final stage of certification. The inclusion of mercury for certification has been initiated. Sediment reference materials for chlorobenzenes and PAHs have been prepared and certification process initiated.

Similarly, about 70 bulk water samples (200 to 1200 litres) were used as reference material for multi-sample, multi-method inter-laboratory studies of inorganic parameters (Figure 4). These samples were also used for national and international quality control studies.



Figure 4.  
Large volume aqueous reference materials.



## Methods Development Program

The Section has been active in advising, adapting, evaluating and developing analytical methods to be used in the Water Quality Branch Regional Laboratories. Three methods on the multi-class, multi-residue analysis of 17 herbicides in water and sediments were developed for the Western and Northern Region laboratory.

## MICROBIOLOGY LABORATORIES SECTION

During the past year, Microbiology Laboratories Section staff concentrated their scientific efforts in the following areas: (a) microbial screening tests for toxic substances; (b) mutagen screening tests; (c) evaluation of acid rain stress on lake microbial populations; (d) evaluation of the effect of 2,4-D application on microbial populations in ponds; and (e) evaluation of the bacterial water quality of Lake Huron.

### Toxicity Screening Tests

A variety of test methods and criteria have been developed to assess the impact of chemical pollutants on aquatic biota. With increasing awareness of the long-term effects of many of these chemical pollutants, research efforts are being directed at short-term bioassay screening tests, the majority of which are unstandardized microbial tests.

To try to bring some standardization to toxicity screening procedures used by Canadian governmental laboratories, studies were undertaken to evaluate the following four microbiological acute toxicity screening tests using single and mixed chemical solutions; Microtox, Spirillum volutans, Pseudomonas fluorescens and Aeromonas hydrophila. One of the major findings was that it is dangerous or unwise to try and assess the presence of toxicants in waters or effluents by a single species test due to the variety of responses that can be obtained with single and mixed chemicals. The battery approach, encompassing two or three genera and involving two to four species, is recommended to more thoroughly assess the potential presence of toxicants.

### Mutagen Screening Tests

The screening of environmental samples for mutagenic activity often requires the samples to be pre-concentrated. To evaluate the efficiency of different sample concentration/extraction procedures our laboratory tested 14 lakes, 12 rivers and seven effluent samples by four procedures: liquid/liquid solvent extraction, XAD-2 and XAD-7 resins, flash evaporation at 45°C and membrane filtration. The resultant subsamples were tested for mutagenic activity using five strains of Salmonella typhimurium, TA98, TA1538, TA1537, TA100, and TA1535. Three different experimental procedures were followed; with the addition of mammalian microsomes (S-9 mix) to the reaction mixture, without the

addition of microsomes, and with preincubation of bacterial cells, microsomes and sample.

The concentration procedure based on membrane filtration of unconcentrated and flash evaporated samples produced the highest number of positive subsamples. The membrane filters were dissolved in 5 mL DMSO. Thus, based on these data a quick inexpensive screening procedure for mutagenic activity is available, as part of the battery approach, by using Salmonella typhimurium tester strains TA98 and TA1538 with S-9 addition on membrane filtered 1X and 10X flash evaporated samples.

The yeast Saccharomyces cerevisiae has been used to develop a mutagen screening test which provides a different spectrum of responses than the Salmonella typhimurium test. Initial experiments indicated that the response of the D7 strain of S. cerevisiae to mutagenic agents was related to exposure time and concentration of mutagen. From this information, a sensitive test using S. cerevisiae strain D7 and XV185 was developed which can be used with and without a metabolic activation system. The procedure is now being applied to environmental samples and forms part of the battery of tests available within the Microbiology Laboratories to screen water and effluent samples for mutagens.

To augment our battery of screening tests for mutagens one of the Microbiology Laboratories Section scientists was also trained in the more medically-oriented mutagen screening tests, the sister-chromatid exchange test and the micronucleus test.

### Microbial Effects of Acid Deposition

In studying the effect of acid precipitation on aquatic microbial biota, approximately 400 water and sediment samples were collected from two acid-stressed lakes, one near Batchawana, Ontario, and the other near Halifax, Nova Scotia, and examined for total, respiring and aerobic heterotrophic bacterial populations, as well as nitrogen and sulfur cycle bacteria. These field studies were augmented with laboratory experiments using acid-stressed water and batch-type fermenter units to illustrate the effects of low pH stress on indigenous microbial flora and microbial degradation processes.

Data from these studies indicated that pH stress does have an effect on bacteria. Although total bacterial populations were similar in stressed and non-stressed lakes, respiring bacteria (active) and aerobic heterotrophs were approximately 30% less in the acid-stressed lakes. Nitrifying bacteria and some sulfur cycle bacterial populations also showed a decrease in acid-stressed lakes. The oxygen uptake rate and degradation rates of organic matter in acid-stressed waters were found to be approximately 50% less than those in non acid-stressed waters. The implications of these findings are that normal biodegradation and biotransformation processes are stressed at low pH and normal turnover activities and food chains are interrupted, thus accelerating the death of the lakes.

## Bacteriological Surveillance

As part of the Microbiology Laboratories Section support of the International Joint Commission Surveillance Program, Microbiology Staff participated in three cruises of Lake Huron and Georgian Bay during which 270 water samples were collected from 67 sampling stations. These samples were tested for bacteria of public health significance-fecal coliforms, fecal streptococci and Pseudomonas aeruginosa as well as trophic indicator bacteria - total populations, respiring populations and oligotrophic bacteria. When these 1980 bacteriological data were compared to those collected in 1974 from the same area, the comparison indicated that there had been no degradation in bacteriological water quality over the six-year period. The present bacteriological water quality of both Lake Huron and Georgian Bay is good and meets all bacteriological standards, and the offshore waters are practically free of fecal indicator bacteria.

## Pond Studies

Microbiology Laboratories staff participated in a multidisciplinary study on the effects of 2,4-D on fresh water pond systems. In this study, six ponds were used and pond water and sediment samples were monitored for geo-aquatic fungi, yeasts, phycomycetes and various microbial populations before and after treatment with different 2,4-D formulations. In general, it was found that the addition of 2,4-D had minimal effect on microbial and mycological populations and a detailed report is now being prepared. Research was also carried out to evaluate mycological media for the enumeration of fresh water yeasts under stress conditions.

## COMPUTER SERVICES SECTION

The Computer Services Section operates and provides system software support for the large-scale scientific computing facilities at the Canada Centre for Inland Waters. Services are provided to all components of the Centre since much of current environmental research is dependent on the availability of adequate computing resources. The Section's work affects many NWRI research programs.

The facilities of the Section include a Control Data (CDC) Cyber 171 computer system supporting batch and timesharing access, a high-speed Calcomp plotting system, two minicomputers, an interactive graphics terminal, and a data entry service.

## Upgrades

Growth of the Cyber 171 workload and improvements in CDC's operating system software resulted in several upgrades during 1981.



In January, the disk subsystem was upgraded by the replacement of three single density disk drives with double density drives. This resulted in a doubling of the public disk space available to the user community.

In April, one seven-track tape drive was replaced with a nine-track drive, resulting in a more effective, balanced tape subsystem consisting of two seven-track and two nine-track drives.

The Cyber operating system was upgraded with the addition of Fortran 5 (the CDC implementation of the ANSI 77 Fortran specification) and Tracer (a performance analysis program). Two new releases of the operating system were installed during the year.

### Software Development

An operating system modification was written and installed on the Cyber 171 to provide users with information about the current status of the input/output and running job queues. With this information, users are made aware of the system workload and can schedule their job submissions to take advantage of slack periods.

An interface between the Calcomp plotter software and the CDC-supplied Interactive Graphic package was written to allow users to generate Calcomp plots from graphic displays. This development eliminated the need to purchase a comparable software package.

Input/output software was written to allow a Summagraphics digitizing table to be connected to the section's PDP-15 minicomputer. Extensive testing was required to determine the operating characteristics of the table and assure reliable results.

### Operations

The volume of work handled by the Section has continued to increase. During the first two years of operation of the Cyber 171 system, the computing workload has increased by more than 100%. Growth in the use of other services has been less dramatic, while the demand for data entry has dropped substantially.

On the Cyber 171 system during 1981, 101,470 batch jobs and timesharing sessions were run and 2,130 hours of central processor time were used. The system was in operation for 4,446 hours and was out of service because of various malfunctions for 25.5 hours, resulting in system availability of 99.4%.

The estimated value of all computing services provided to CCIW by the Section was in excess of \$880,000 in 1981.



**AQUATIC PHYSICS AND SYSTEMS DIVISION**





The Aquatic Physics and Systems Division (APSD) of NWRI conducts a program of research incorporating balances of experimental measurements and numerical, theoretical analyses. Emphasis is placed on physical understanding of the dynamics of inland waters through investigation of the circulation, mixing and diffusion processes of lakes as these factors interrelate with and control the distribution of dissolved or suspended materials such as biological nutrients, contaminants or radionuclides. Optical characteristics of natural waters are investigated as related to applications of spectro-optical characterization from in situ, airborne or satellite-borne sensors. Numerical systems models are developed employing both deterministic and stochastic analysis to simulate both physical or biochemical processes in lakes, streams or other components of the aquatic regime. In close support of the research program of this Division and of other research units of CCIW, a Data Base Management Section maintains archives of environmental data and provides assistance in scientific computer programming. This data base management function is a direct contribution to large-scale environmental surveillance such as the IJC Great Lakes Water Quality Program, the Global Water Quality Monitoring Program, the Toxic Contaminants Management Program, and the Long-Range Transport of Airborne Pollutants Program.

The research of the Division is organized into three Sections and a special task contribution to the Interdepartmental Long-Range Transport of Airborne Pollutants program. These are:

- (i) Basin Investigation and Modelling Section
- (ii) Spectro-Optics and Remote Sensing Section
- (iii) Data Management Section
- (iv) Long-Range Transport of Airborne Pollutants Task.

#### **BASIN INVESTIGATION AND MODELLING SECTION**

The research activities of the Basin Investigation and Modelling Section have been traditionally divided into two major headings: (1) Physical Limnology of Lakes and (2) Environmental Simulation.

##### **Physical Limnology of Lakes**

The general objective of the Physical Limnology Program is to describe and to quantify through field observations, analyses and theoretical studies, the physical limnological processes that take place in lakes and which affect the water quality. Some recent physical limnology research programs where there are direct linkages between water movement and water quality are described in this report.

##### **Lake Erie Studies**

Work continued in 1981 with the reduction and analysis of the data collected in Lake Erie during the summers of 1979 and 1980. These experiments were designed to investigate some of the physical processes

affecting the transfer of dissolved oxygen to and within the hypolimnion of the Central Basin. Examples of these processes are entrainment into a turbulent hypolimnion and the resuspension of bottom sediments.

The analyses performed to date have confirmed the findings of the earlier Project Hypo experiment that there is a broad area in the Central Basin of nearly uniform physical and chemical properties. The spectra of the bottom currents show that most of the energy resides in the long-period motions associated with meteorological disturbances, with a further strong peak associated with the inertial period and the fundamental surface seiche (14 to 17 hours). Below 10 meters depth, currents averaged over 48 hours move counter to the prevailing wind (allowing for the effects of the earth's rotation) and there is evidence that this mean transport, rather than turbulent diffusion process, may dominate horizontal transports within the hypolimnion.

Concerning vertical transports, Ivey and Boyce, in a paper recently accepted by the Journal of Limnology and Oceanography, have found direct evidence for the hitherto suspected entrainment of mesolimnion water into a turbulent hypolimnion (Figure 1). This process has been cited by earlier workers as an important contributor to the oxygen supply of the Central Basin hypolimnion. The process seems to require specific preconditions, and was identified only twice during the 1979 stratified season. Its importance in other years could be evaluated from historical meteorological and temperature profile data.

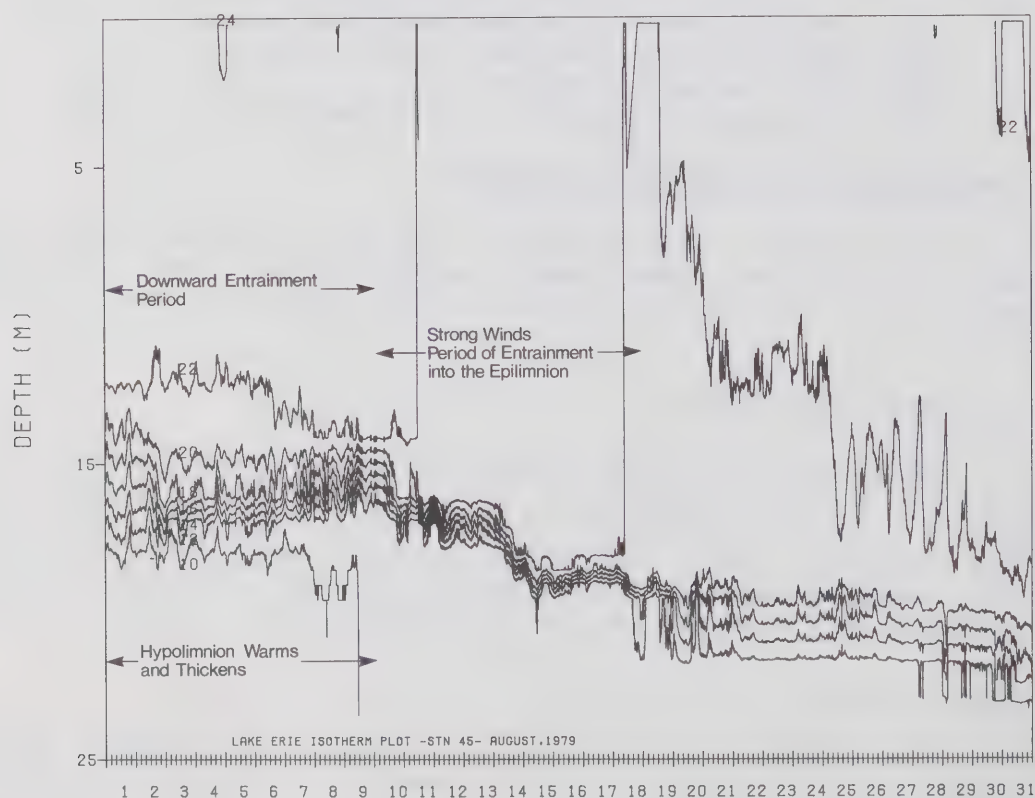


Figure 1. Lake Erie isotherm plot for station 45, August 1-31, 1979.



## Lake Ontario Studies

In preparation for a major experimental program on Lake Ontario in 1982, a comprehensive analysis of historical data and review of pertinent models were initiated to describe expected current patterns along the north shore of this lake. Data collected near Oshawa in the winter of 1973/74 and near Pickering in the winter of 1979/80, show that these coastal zones are characterized by periodic reversals of along-shore currents with typical periods of five to ten days. Such current reversals are of the greatest importance for the dispersal of heat and pollutants in the nearshore zone and essentially determine the shape and orientation of effluent plumes. From theory it is known that the sloping bottom of the coastal zone can give rise to current reversals associated with topographic waves propagating along the shore, but in practice it is difficult to separate this effect from other influences such as local wind forcing. A series of model experiments with idealized and realistic lake configurations were carried out to clarify the various processes entering into this picture. The conclusion was that the topographic mechanism plays an essential role but the waves are damped rapidly by bottom friction in shallow water and therefore must be continually reinforced by surface winds.

Some results from a two-dimensional numerical model of Lake Ontario are illustrated in Figure 2. In this case, the forcing consists of a brief wind impulse and the model computes the resulting alongshore current at distances of 2, 7 and 12 km, respectively, from the Oshawa shore. Nearshore, a strong current in the direction of the wind is generated initially, but it is damped immediately by friction. Farther offshore, the initial current is weaker but it is followed by a series of current reversals due to topographic wave effects.

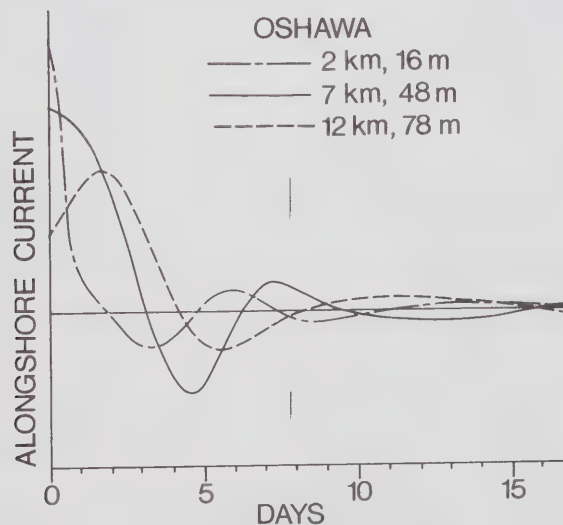


Figure 2. Results from a two-dimensional model of Lake Ontario illustrating the temporal response of alongshore currents to a brief wind impulse. The currents have been computed for distances of 2, 7, and 12 km from the Oshawa shore.

## Kootenay Lake Studies

A review of the dynamics of water bodies has been completed in which a number of non-dimensional parameters relating to physical processes in lakes were developed. Three of these parameters quantify whether or not the long-term development of the thermal and dissolved material distributions may be simulated by either a one or higher dimensional modelling approach. It was concluded from analysis of data collected in Kootenay Lake, 1976-1977, that water quality could be simulated by means of a horizontally-averaged model, but with special attention to the parameterization of such two- and three-dimensional effects as internal seiches which contribute to mixing in the thermocline region.

Observed time histories of the depths of isotherms and isohalines over an 18-month field study period are compared with the corresponding plots of simulations in the accompanying figures. The modelled distributions which were initiated with data from the first cruise and then hindcast from observed winds, air temperatures, relative humidity, light extinction, solar and long-wave radiation and volume, temperature and salinity of major inflowing rivers are seen to replicate the major features of the time histories such as the timing and degree of the thermal stratification and its interannual variation. Interestingly, a winter temperature inversion is predicted, as well as the winter halocline which supports this inversion. One conclusion is that hydrodynamic modelling of long-term property distributions in deep lakes needs improved understanding of processes responsible for mixing, particularly in the hypolimnion.

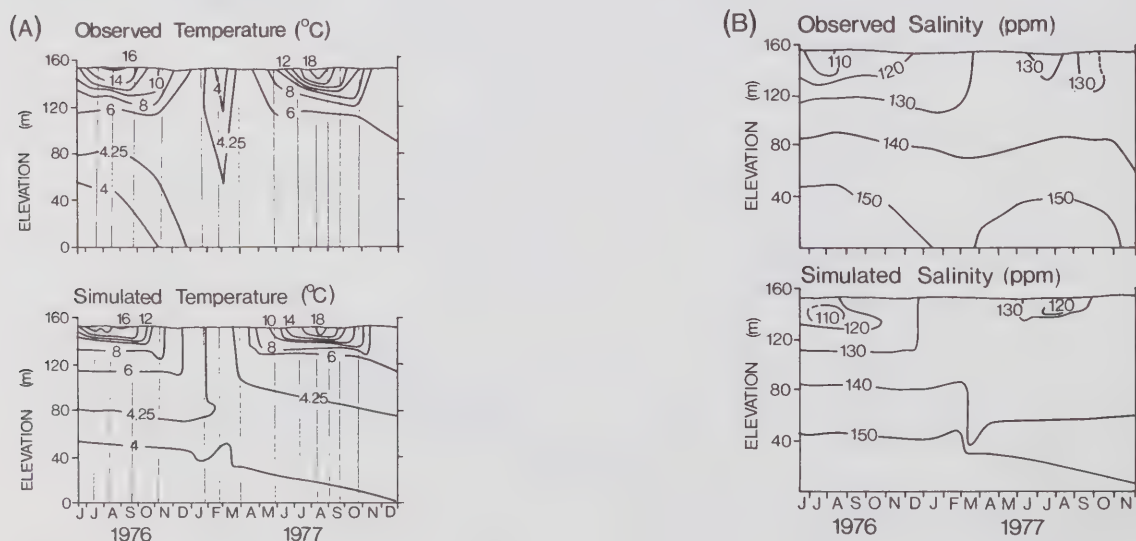


Figure 3. Observed and simulated time histories of the depths: (a) isotherms; and (b) isohalines, June 1976 to December 1977, Kootenay Lake, B.C.

## Environmental Simulation

The main objective of the Environmental Simulation Program is to develop a general modelling framework which simulates the temporal and spatial distributions of dissolved and suspended materials in the nearshore and offshore zones of lakes. Based on the general framework, basic limnological research results in the physical, chemical, and biological sciences can be synthesized into overall simulation models which are capable of simulating the effects of contaminants in the aquatic ecosystem.

### Lake Erie Water Quality Model

Simulation of Lake Erie water quality responses to loading and weather variations were conducted utilizing physical and biochemical data analyzed for the period 1967 to 1978. Implementation of the phosphorus removal program and extremes of weather conditions during this period enabled detailed analysis of Central Basin hypolimnion oxygen depletion in response to man-made effects of nutrient reduction and the natural influence of meteorological and limnological processes. The framework for water quality simulation was a three-basin, three-layer (e.g. 9-box) mass balance model. The 9-box framework is a model of intermediate complexity meeting requirements of long-term predictability with sufficient spatial details and belongs to a hierarchy of models of varying spatial complexity. For example, thermal layer boundaries in the 9-box model are determined by using a one-dimensional ( $z$ ) thermo-cline model.

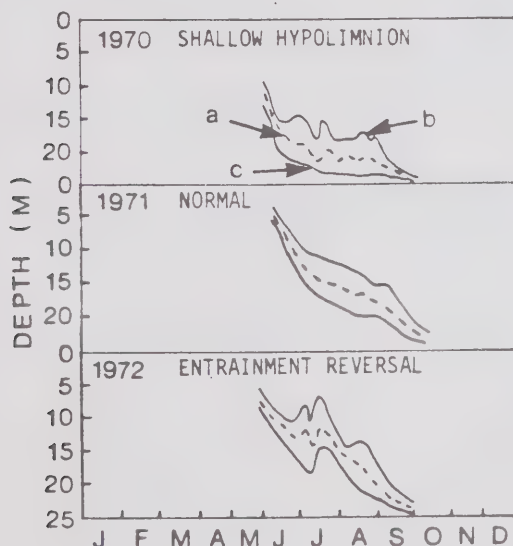


Figure 4:

Examples of computed Central Basin thermal layer boundaries illustrating three basic thermal regimes in response to weather phenomena: (a) thermocline; (b) top of the mesolimnion; (c) bottom of the mesolimnion.

The one-dimensional thermocline model allows for dynamic changes in the thermal layers defining the epilimnion, mesolimnion and hypolimnion of the 9-box model. The novel feature of this design is that it allows for computation of daily changes in water level, hydraulic flow, vertical entrainment, eddy diffusion and interbasin transports between basins and layers. These physical processes apply to



all variables in the three-component (soluble reactive phosphorus, organic phosphorus and dissolved oxygen) biochemical submodel. Figure 4 shows examples of computed depths of the Central Basin thermal layer boundaries illustrating three basic thermal regimes in response to weather phenomena. In the 'shallow hypolimnion' type, the sediment oxygen demand is able to substantially deplete the oxygen in spite of the biological production and physical sources. This leads to biochemical regeneration of soluble reactive phosphorus ammonia and even hydrogen sulphide from the sediment. In the 'entrainment reversal' type, the formation of the thermocline is disrupted by storm events, and large supplies of oxygen due to wind mixing and upward entrainment prevent the onset of anoxia. The effect of 'normal' thermal structure is intermediate between these extremes.

Figure 5 shows computed and observed concentration of total phosphorus for the Central Basin hypolimnion. In the winter time, phosphorus concentration increases due to physical resuspension for the fully-mixed period between November and March for nearly every year, whereas anoxic release of phosphorus occurs more prominently in September or October in 1969, 1970 and 1977. Dissolved oxygen concentration in the Central Basin hypolimnion also undergoes seasonal cycles and the extent of anoxia is influenced by the weather-induced thermal structure types.

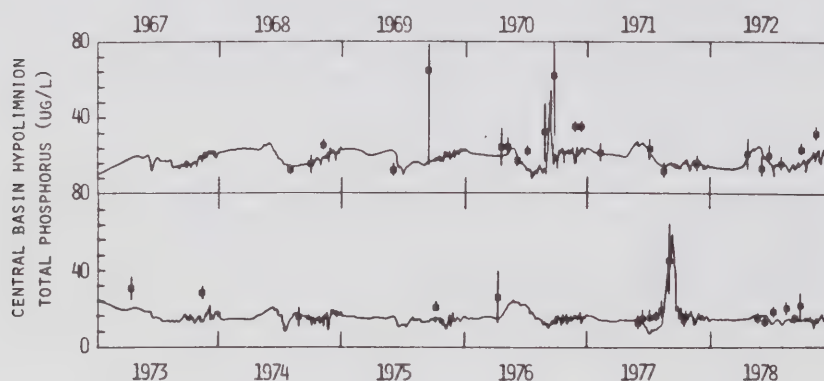


Figure 5. Comparison of computer (—) and observed ( ■ ) Total Phosphorus concentration for Lake Erie Central Basin hypolimnion using a 9-Box mass balance model for the period 1967 to 1978.

The outcome of the simulations is a more accurate prediction of Lake Erie water quality and allows the construction of equilibrium response curves detailing lake water quality changes to both loading and weather variations. By using the twelve-year meteorological data base 1967-1978 as a climatic cycle with the loading fixed at a constant rate, the results at the twelfth year (1978) represent an equilibrium concentration reached in the climatic cycle. Intermediate results such as in 1970 and 1972 are representative of the 'shallow hypolimnion' and 'entrainment reversal' weather effects on the thermal structure, respectively. These latter two equilibrium concentrations provide the upper

and lower bounds of the weather influences. By computing different equilibrium concentrations for different loading rates, response curves of lake concentration to loading are obtained. Figure 6 shows the estimated equilibrium dissolved oxygen response of the Central Basin hypolimnion to phosphorus loading reduction under average, favourable and adverse weather effects.

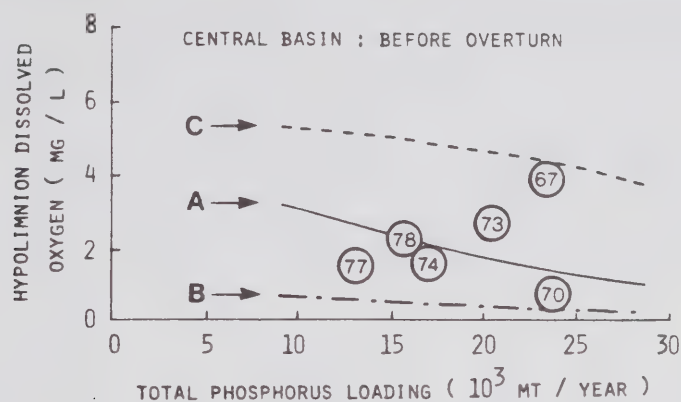


Figure 6: Equilibrium response curves of Central Basin hypolimnion dissolved oxygen just before fall overturn vs. phosphorus loading level. Curves A, B, and C denote responses under averaged, unfavourable and adverse weather, respectively. Circles with numbers indicate year of 'non-equilibrium' observations.

### Coastal Transport Models

The nearshore transport modelling efforts at NWRI have been oriented towards developing a general package for simulating the advective and diffusive processes in the coastal zone regime, with particular emphasis on the nearshore-offshore exchange of pollutants. By means of calibrating with dye concentration data collected from environmental diffusion experiments, a finite element package has been developed. It has been found that the scale-dependent diffusivity produced a more satisfactory comparison with observed data than the constant diffusivity approach. To demonstrate the applicability of the model for industrial pollution problems, it has been used to simulate the tritium release episodes in Lake Ontario coastal waters near the Pickering Nuclear Power Generating Station. By incorporating the shoreline configuration, discharge and intake velocities, and measured currents, a mass-consistent flow field has been produced and used in the finite element model. Figure 7 shows the observed and computed tritium concentrations where two distinct patches of pollutants can be identified as a result of two separate discharges. While the radioactive levels of the tritium concentration are well within the safety standard, the model is capable of simulating the peak concentration and the diffusion characteristics.

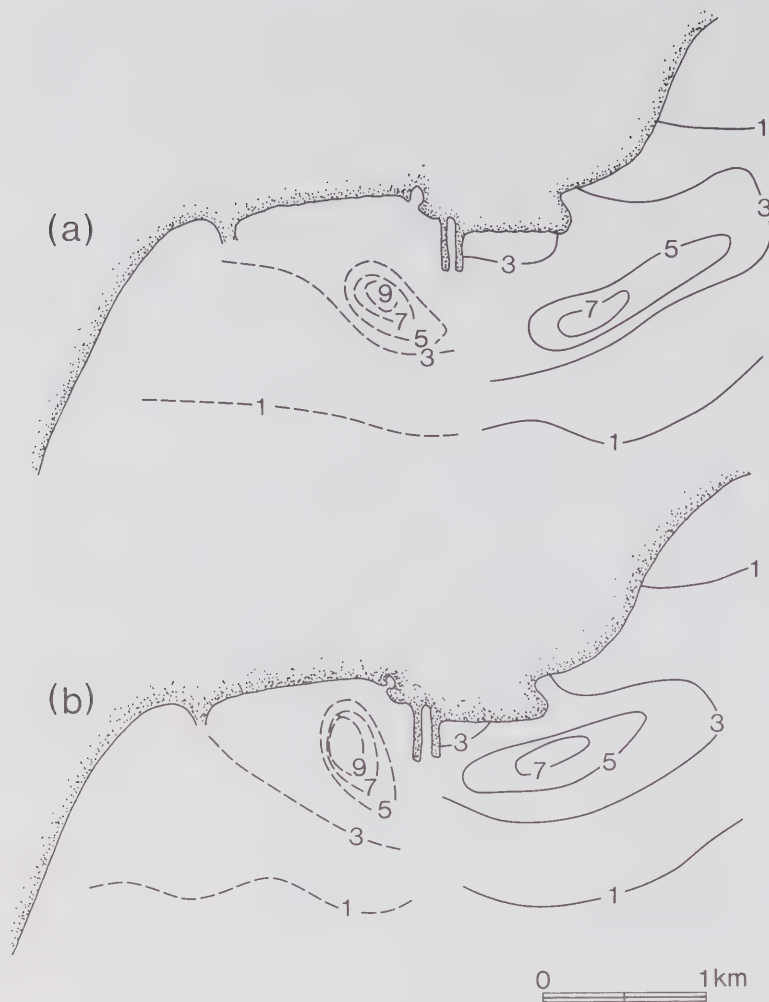


Figure 7.

Observed and computed tritium concentration near the Pickering Power Generating Station.

(a) Observed and (b) computed tritium concentrations (x 1000 pCi/L) at EDT 1046 hr. (---) and 1148 hr (—), Sept. 30, 1975, near the Pickering Nuclear Power Generating Station, Lake Ontario.

For simple straight plume cases, a fast algorithm can be used to obtain predicted concentration under the same scale-dependent diffusion assumption. By utilizing the statistical distribution of directions and magnitudes of observed currents, the dilution factor for a specific site can be derived by taking into account the frequency of occurrence of different types of currents. The simulated plume sizes can then be averaged and viewed as the averaged plume size for a conservative pollutant to disperse at that particular site. This coastal dispersion model has the capability of defining the so-called "mixing zones" for which pollutants may be expected to exceed certain dilution levels. Table 1 summarizes the simulated plume characteristics in order to achieve a dilution factor of 100:1 in the coastal zones of Lake Ontario near Lakeview, Ontario.



Table 1. Simulated Plume Dimensions at the Lakeview W.P.C.P. Site, Lake Ontario.

The plume dimensions are the computed length and width of a specified dilution (100:1) contour averaged over several episodes for the same range of observed currents. Only the results of shore-parallel and shore-antiparallel flows are presented. Results of stagnation and other flows (which comprise 57.8% occurrence of flows in summer and 22.9% in winter) have not been shown.

	Speed (cm/s)	Frequency (%)	Diffusion Time (min)	Length (km)			Width (km)		
				min	mean	max	min	mean	max
S Shore	0-5	8.5	805	1.2	1.5	2.4	0.4	0.6	0.9
U Parallel Flow	5-15	11.0	670	1.0	2.5	6.0	0.3	0.5	1.0
M	>15	-							
M Shore									
E Antiparallel	0-5	8.9	1155	1.3	1.8	4.0	0.3	0.6	0.9
R Flow	5-15	13.8	900	1.3	3.4	7.4	0.3	0.5	1.3
	>15								
Shore	0-5	10.0	1370	2.7	3.2	4.2	0.3	0.5	1.0
W Parallel Flow	5-15	25.7	1340	3.7	6.2	11.0	0.3	0.6	1.1
I	>15	7.0	1765	16.1	16.2	16.3	1.0	1.0	1.0
N									
T Shore	0-5	12.3	1665	1.3	2.8	3.7	0.3	0.8	1.5
E Antiparallel	5-15	17.2	1215	1.3	4.6	7.1	0.3	0.5	1.5
R Flow	>15	4.9	1190	4.0	9.7	14.6	0.5	0.5	0.9

### Toxic Substances Modelling

Within the environmental simulation program a research project is directed to the investigation of the fate of toxic substances in the aquatic environment. Toxic substances enter the rivers and the lakes of Canada from point sources, non-point sources and the atmosphere. Point sources are discharges from industrial plants or wastewater treatment plants, and non-point sources are mostly of agricultural origin or originate from leaks from unmonitored dumps. Once they reach the water, the toxic substances are dispersed according to their chemical properties as well as according to the physical and geological properties of the lake or the river. For example, a hydrophobic substance will tend to rapidly adsorb on sediments with a high percentage of organic carbon, other substances will volatilize at the water surface and return to the atmosphere, and still others will be degraded by microorganisms, photolyzed, oxidized, or hydrolyzed. In the environmental simulation program all these accumulation and degradation processes are quantified and described with mathematical formulations. The equations, usually differential equations, combine the chemical properties of the chemical with the observed environmental properties to predict the fate of the substance in the aquatic environment. Some substances may accumulate in

the pelagic food chain, while others may accumulate in the benthic food chain. Some chemicals are broken down fairly rapidly in a few hours or days, and others may remain in the environment for many, many years. Some of these persistent compounds are extensively studied; for example, PCBs and Mirex.

During the past year, two models were completed. One describes the fate of fenitrothion aerially sprayed in New Brunswick, and the other describes the fate of Mirex in Lake Ontario. Fenitrothion is used extensively to kill the spruce budworm, an insect that is able to rapidly destroy thousands of acres of forest in Ontario, Quebec, New Brunswick and the northeastern United States. Fenitrothion is sprayed from aircraft over the forests; however, some is sprayed over ponds, where it affects the local fauna. Observations of the fate of fenitrothion are of necessity limited in numbers. Furthermore, the first measurements are usually taken, not sooner than about 40 minutes after the aircraft overflight, to avoid exposure to the scientists. Mathematical models are therefore used to estimate how much pesticide was sprayed on the pond from the aircraft (taking into account fenitrothion degradation during the initial 40 minutes) and to predict the amount of time it will take for the fenitrothion to disappear. For some ponds the model predicted that the average time would be 54 hours, but that a safer estimate would have been 66 hours. This modelling approach can also be extended to fish farms. For example, some ponds are routinely sprayed with pesticides to kill fish parasites before fish are introduced. Models can be used to predict the minimum time that must be allowed after spraying before the introductions of fish so that they are not affected.

Another model for Mirex, a pesticide, was developed for Lake Ontario. The purpose of this model was threefold, to predict the amount of time the lake would need to get rid of the Mirex already accumulated in the bottom sediments, to understand Mirex cycling within the ecosystem, and to identify the important physical, chemical, biological, and geological characteristics that would regulate Mirex behaviour in the lake. Research confirmed that Mirex is very persistent and might remain in the bottom sediments for the foreseeable future. Also, some of this Mirex is bioavailable and continued research is necessary to establish the degree of Mirex mobility at the water-sediment interface. For example, turbulence at the water-sediment interface is an important physical factor that determines Mirex bioavailability. The latest complete survey for Mirex in Lake Ontario was made in 1968 by Holdrinet et al. The model can be used to produce a map of the anticipated concentration patterns (Figure 8) in the bottom sediments of the lake. This expected pattern for 1982 can be compared with observations, when these become available, and with past distributions, to estimate changes and possible critical developments.

# Estimated Concentration of Mirex, Lake Ontario 1982

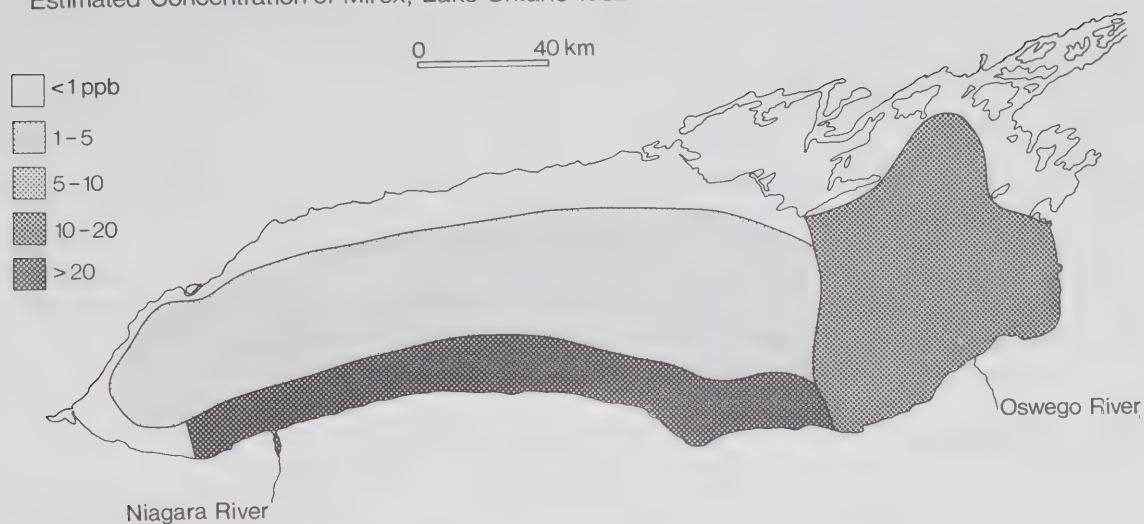


Figure 8 Predicted Mirex distribution in the bottom sediments of Lake Ontario in 1982. Concentrations are in ppb (parts per billion or ng per gram). Since 1968 the main source of Mirex has been the Niagara River. Computations show that since 1968 an additional 1500 kilograms entered the lake. The predictions in this figure have not as yet been verified.

## RESEARCH APPROACH

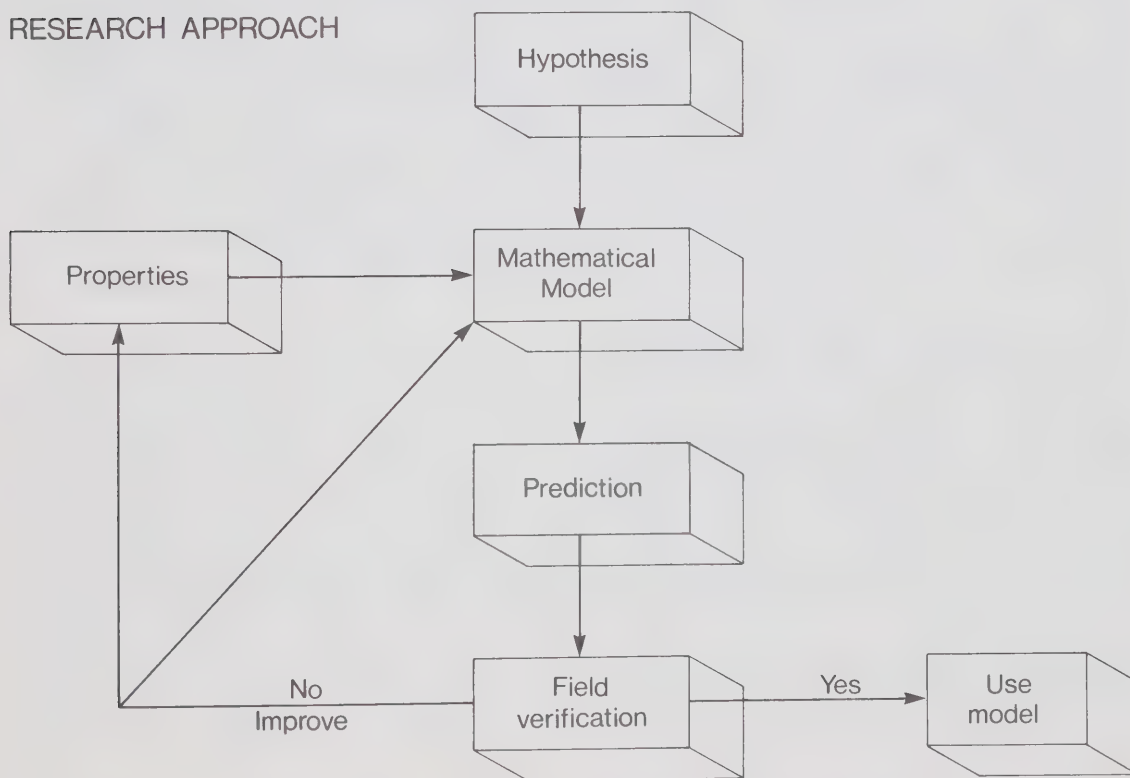


Figure 9. Research approach used in the system modelling process.



In the future, emphasis will be placed on the understanding of the interaction of chemical substances and the critical processes such as turbulence at the water-sediments interface which regulate the fate of some toxic substances. In the system approach used in the modelling process, the focus of research is the study of the relationships among the various ecosystem components. Field and laboratory results are integrated into a mathematical framework and, once predictions are available and have been compared with existing data, suggestions can be expressed to focus research on those specific areas whose understanding is more critical to the successful prediction of the toxic chemical fate. If these suggestions are followed, then new field and laboratory experiments can be planned and executed to answer specific questions, which in turn will produce better predictions (Figure 9).

### Climate Modelling

As part of the Canadian Climate Program, a modelling study was undertaken to couple an upper ocean model with the atmospheric circulation model presently in use at the Canadian Climate Centre. The principal purpose of the oceanic model component is to predict changes of the sea surface temperature in response to atmospheric inputs of heat and momentum at seasonal time scales. Since seasonal temperature variations are confined to the upper few hundred meters, the main problem is to simulate turbulent vertical mixing of heat. The development and verification of this aspect of the model relied heavily on extensive data sets available from the Great Lakes. Contributions from heat transports by large-scale circulations and vertical motions due to divergence of wind-driven currents were estimated from seasonal heat budgets for the northern hemisphere oceans. These effects were then included in the ocean model although, in most cases, they were negligible compared to turbulent mixing. A detailed description of the model structure and evaluation may be found in the NWRI report: "The seasonal climate of the upper ocean: data analysis and model development" by T.J. Simons. Experiments are currently underway to couple the ocean model with the atmospheric model of the Canadian Climate Centre.

### SPECTRO-OPTICS AND REMOTE SENSING

The Environmental Spectro-Optics Section at NWRI conducts experimental and theoretical research concerned with the optical properties of the aquatic environment. The principles of spectro-optical physics and radiative transfer theory are utilized to determine the detailed nature of the interaction of incident radiation with natural water masses. Such information, coupled with model and methodology development, is then directed towards limnological applications. Multi-spectral data collected from in situ, airborne, and satellite optical sensing devices are integrated into the Section's activities and efforts. Recently, the Section has introduced a hydrogeological component into its overall program, the purpose of which is not only

to provide the required linkages between lake and ground water interactions, but also to respond to the current need to extend applications of remote sensing to basin issues and concerns. During the past several years, most of the Section's effort was concentrated on the Laurentian Great Lakes. Some of the pertinent studies included:

- i) The development of in situ optical models which were directly applied to water quality determination from sensors mounted below and above the water/air interface.
- ii) The design and fabrication of an upwelling/downwelling radiometer system for the remote measurement of water quality parameters from a moving ship.
- iii) The design and fabrication of a tower-mounted profiling irradiance system for eventual use in time-series studies.
- iv) A theoretical and experimental study of the effects of solar zenith angle variations on the subsurface irradiance levels.
- v) The development of a duo two-dimensional deterministic model of contaminant transport through an anisotropic unconfined aquifer, and the application of this model to the transport of radioactive contaminants across a lake/lake bottom interface.
- vi) The development of predictive methodology compatible with the Section's digital analysis and display system, and directed towards the determination of chlorophyll, suspended mineral, and dissolved organic carbon concentrations from direct measurements of the subsurface irradiance reflectance spectra of natural lake water.

Figure 1 illustrates the salient experimental and theoretical steps followed in the development of predictive water quality methodology. Direct optical measurements performed from ship-transported submersible sensors capable of obtaining in situ subsurface irradiance reflectance spectra are utilized in radiative transfer models to determine optical cross-sections (i.e. the amount of absorption and scattering occurring within the water column per unit concentration of lake component) appropriate to the water body. These cross-sections, in turn, form the basis for the development of water quality models.

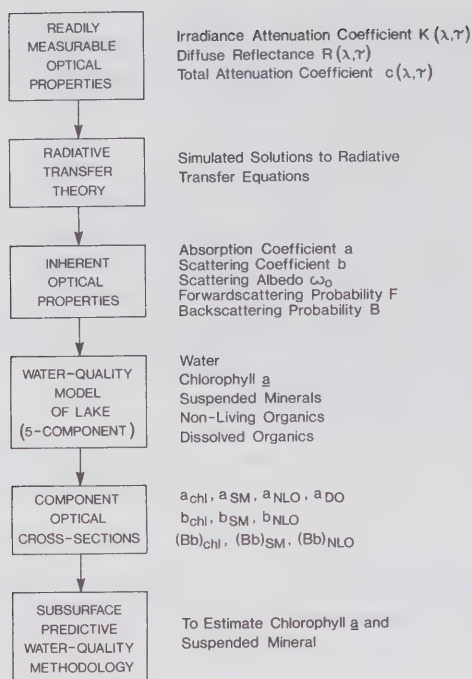


Figure 1. Experimental and theoretical steps followed in the development of predictive water quality methodology.

Figure 2 illustrates such methodology developed for use with the 520 nm and 670 nm wavelength bands of the Coastal Zone Color Scanner mounted aboard the earth-orbiting satellite NIMBUS-7. Direct application to NIMBUS-7 would require the development of a reliable, as yet highly elusive, atmospheric correction algorithm. Each point on the duoisoplethic curves is defined by the coordinates (Chl a, suspended mineral).

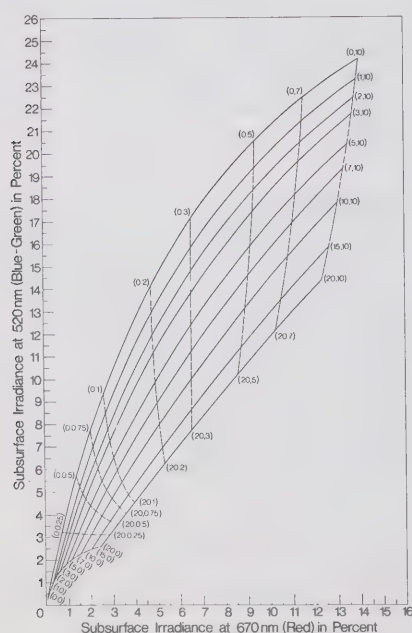


Figure 2. Predictive water quality methodology developed for use with the 520 nm and 670 nm wavelength bands of the NIMBUS-7 Coastal Zone Color Scanner.



Figure 3 displays the depth of the 1% subsurface irradiance level as directly measured for three midlake stations in Lake Erie as a function of solar zenith angle. Curves A and B illustrate the solar zenith angle response functions predicted for two "clear day" incident radiation distributions.

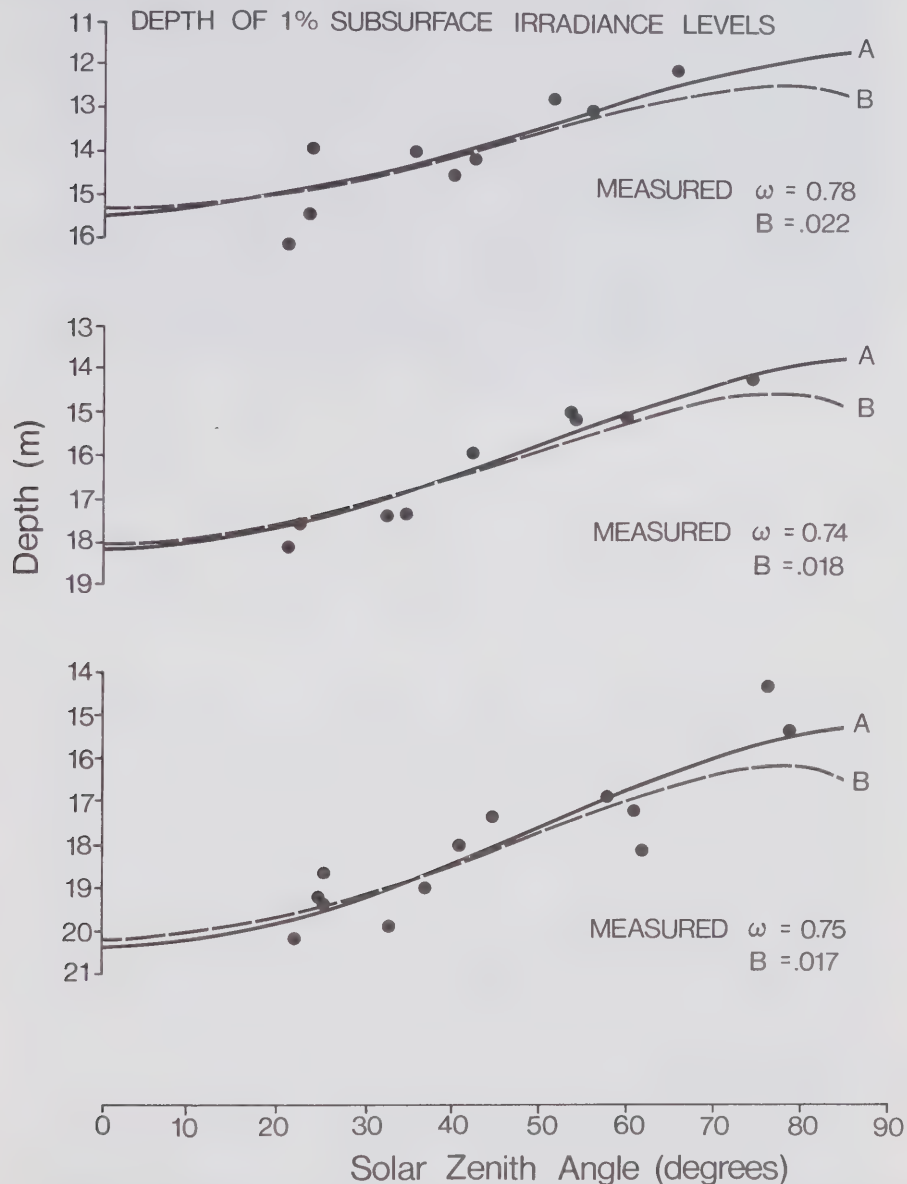


Figure 3. Measured and predicted depths of the 1% subsurface irradiance level as a function of solar zenith angle for three midlake stations in Lake Erie, 1979.

Figure 4 illustrates the steady-state solution (for continuous contaminant injection from a waste disposal site located at the origin) arising from the contaminant transport model. The iso-concentration profiles shown represent the dispersive and convective transport along

the surface (the abscissa) and beneath the surface (the ordinate) with the passage of time for an aquifer system characterized by a groundwater flow velocity with a lateral component 20 times greater than its vertical velocity. Note the distinct, albeit limited, contaminant transport apparent in the upstream direction behind the source, a consequence of molecular dispersion acting in opposition to the forcing velocity.

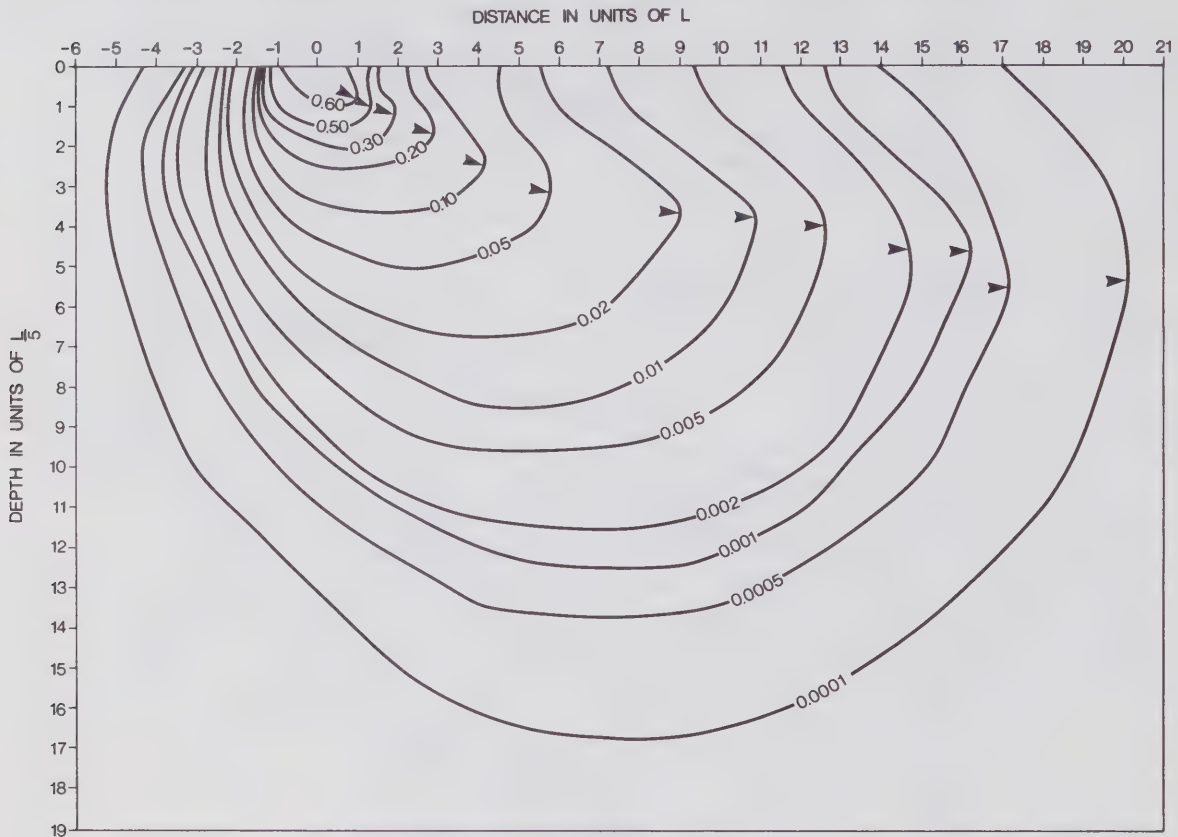


Figure 4. Contaminant transport model steady-state solution illustrating iso-concentration profiles resulting from continuous contaminant injection at origin.

## DATA MANAGEMENT SECTION

### Roles and Responsibilities (MANDATE)

The Data Management Section of APSD, NWRI, provides all departmental components at the Canada Centre for Inland Waters with operational data management services for major environmental data bases, including data reduction, editing, quality control, file maintenance, data retrieval and security services. Equivalent services are also provided for research scientists' data sets on request.



**Figure 1.** Secure storage of data on magnetic tape in a 4-hour, fire-rated vault.

Computer systems design and programming staff of the Data Management Section provide EDP systems development services in accordance with approved allocations by program. All allocated support services are monitored and accounted for by scientific study, organization and by program.



**Figure 2.** Office environment for computer system design and research application development.

The Data Management Section has a mandate to act as the Global Data Centre for a United Nations' sponsored fresh water monitoring system. The Section has assumed full responsibility for the design,



development, maintenance and operation of the Global Environmental Data Base, including production and global dissemination of data summaries. Response to special or ad hoc requests for regional or global analyses is also being provided on request.

A responsibility of major importance is in the development of EDP facilities for the integration of various national and regional data bases for scientific modelling applications.

Specialized technological support services are rendered on an allocated basis to other components of the Department and another Department residing at CCIW. These include production of software used in the reduction, conversion and production of maps and charts, the automation of large complex chemical laboratory functions including laboratory management functions, process control functions, and data reduction and conversion functions. As well, data base management, data quality control, reporting and data file updating services are supported.



Figure 3. Automated chemical laboratory equipment linked to centralized computer facilities.

A further mandate has been given regarding the use of mini-computers in specialized EDP applications related to the environmental sciences within NWRI. These include the automated visual scrolling of time-series data for editing purposes, the development of colour graphics facilities for the subjective evaluation of satellite imagery information, data acquisition systems development, laboratory control systems, and other specialized applications.

A final major role is the provision of consultation services for a large community of scientists and technicians (80-100) engaged in programming activities related to their own studies. Consultation is also provided by the Section Head to Centre management in relation to

ongoing and projected computing needs and computer-related problems related to other management functions within the Department.

### **Major Activities Undertaken**

Software systems design and development support were provided on a monitored basis and to an approved plan for all organizational components at CCIW totalling 74 different studies.

The major Acid Rain data base system and analysis facilities were expanded to meet added study requirements for eastern Canada.

The major automated laboratory data acquisition systems were maintained and enhanced.

The UNEP/UNESCO global environmental monitoring support EDP system was enhanced and operated. An interim data report was prepared for UNESCO covering six regions encompassing the globe.

Interactive graphics facilities in support of research were developed as required including implementation of new digitization hardware and software during 1981/82.

An evaluation of toxic substances data stored at NWRI was undertaken with a view to development of an appropriate integrated data base structure.

A Centrewide review and projection of program-related computing requirements were initiated in anticipation of computing facilities saturation within one to two years.

Major involvement in the selection and implementation of word processing, office automation and communications facilities has begun and will expand in 1982/83.

The entire NWRI inventory management system has been implemented on an inter-active computer system.

A Management Information System to support program planning is being developed and implemented on behalf of NWRI management.

### **Technology Implementation Achieved**

All substantive data bases have been reimplemented under a modern Data Base Management System for vastly improved access to data by or on behalf of scientists.



Figure 4. The above magnetic disk pack will accommodate ten years of data from the Global Environmental Monitoring Scheme.

Major operational data bases such as Great Lakes surveillance and global (GEMS) data have been micrographically reproduced for convenient national library access and global dissemination.

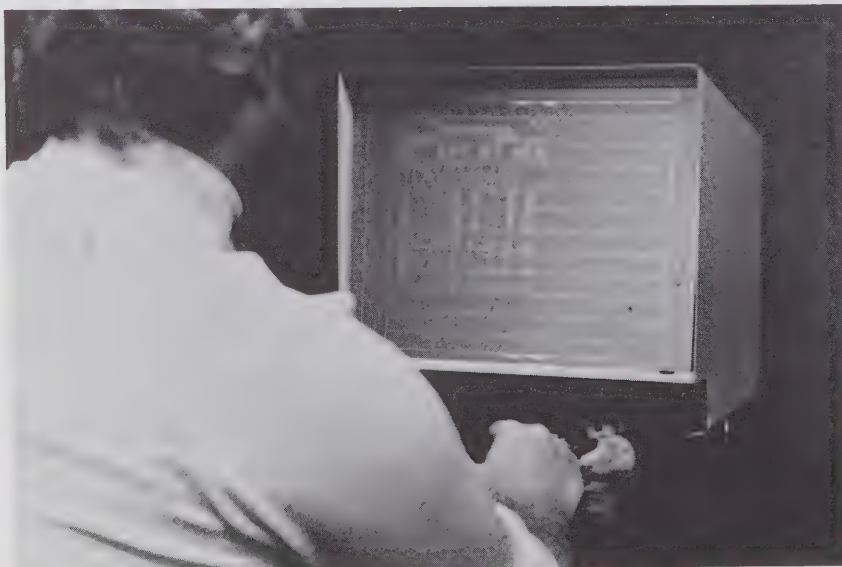


Figure 5. Visual Retrieval of data from a computer-generated microfiche containing 279 pages of information.

The entire CCIW computer user community of 150 persons (including 30 to 40 transient summer staff) were trained and assisted in a rapid conversion to interactive computer usage and newer levels of technology application are under active evaluation.



## LONG-RANGE TRANSPORT OF AIRBORNE POLLUTANTS

### Aquatic Regime Acidification: Models and Monitoring

Evaluating the impact of acid precipitation on aquatic systems requires obtaining reliable data on surface water chemistry in the impact areas. The best and most useful set of data obtained thus far has been the routine monitoring data collected by Water Quality Branch in Atlantic Canada, analyzed in their Moncton, N.B. laboratories, and stored in NAQUADAT. Data tapes were supplied by Water Quality Branch, and retrieval programs that listed the data in a useful format, performed several quality control tests, and calculated useful relationships were written by staff of the Data Management Section. Evaluation of these data has led to the discovery of a natural exchange of marine sodium for freshwater calcium on some as yet unspecified exchanger in the basins of various coastal rivers. The data were also used to develop a model that relates the excess  $\text{SO}_4$  in runoff to the median pH of the river (Figure 1).

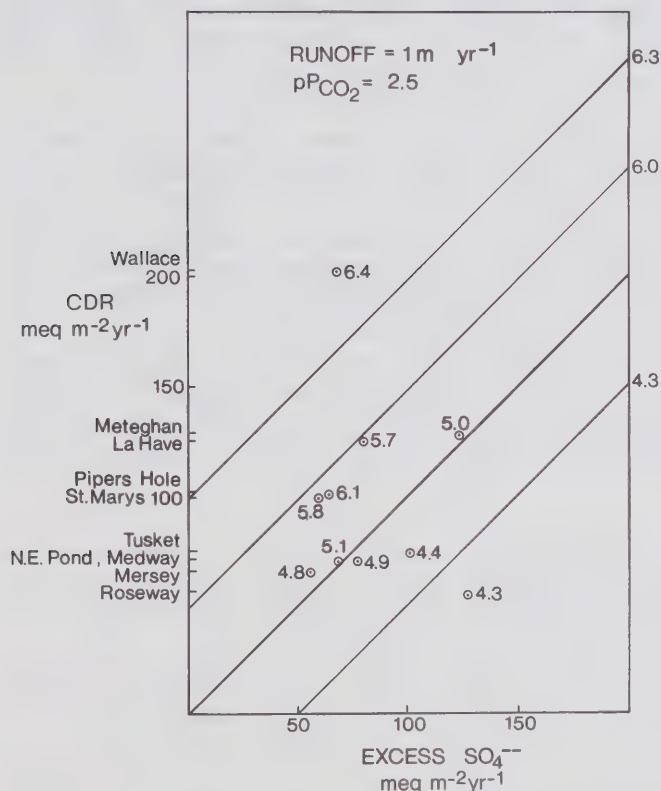


Figure 1.

A plot of the model that relates the cation denudation rates of rivers, the excess  $\text{SO}_4$  carried by the rivers, and the median pH of the rivers, showing data for ten rivers in Atlantic Canada with mean runoff near 1 m  $\text{yr}^{-1}$ .

Other water quality data, especially for lakes, have been and are being, accumulated and evaluated for all Ontario, Quebec and Atlantic Canada. The cooperation of many scientists in federal and provincial agencies, in universities, and in research institutes is much appreciated. Data on the  $\text{SO}_4$  content in lakes in Canada and northern Wisconsin, from ELA (Kenora) in the west to Labrador in the east are shown on Figure 2.

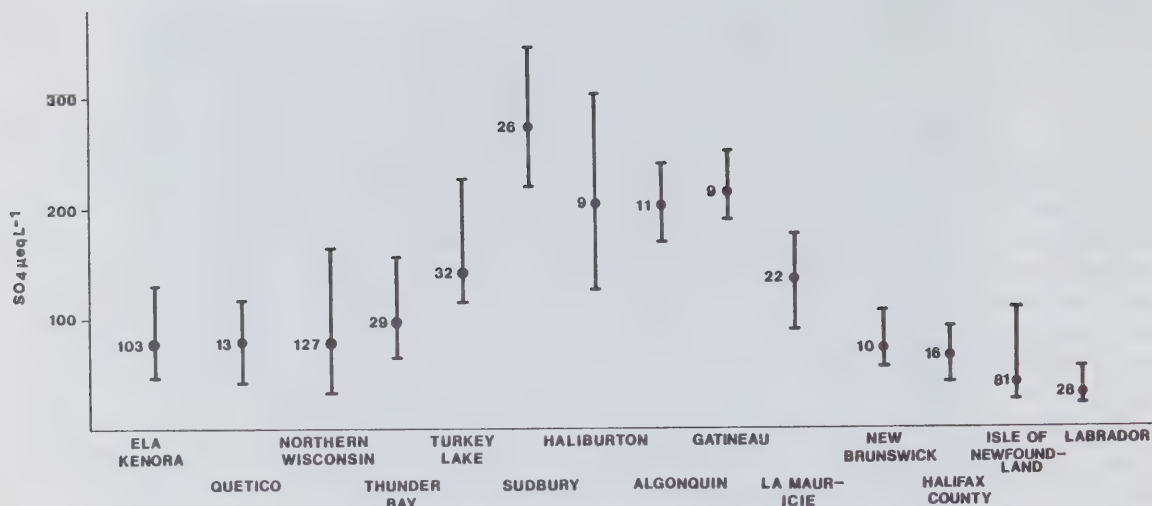


Figure 2. The mean and range of  $\text{SO}_4$  (near the coast excess  $\text{SO}_4$ ) in lakes and some streams from ELA (Kenora) in the west to Labrador in the east. The numbers indicate the number of lakes or streams. Sampling dates ranged from 1973-1981.

In contrast to previous years, 1981-82 was spent principally in examining lake data. Data for lakes from ELA (Experimental Lakes Area, Kenora, northwest Ontario) in the west to Labrador and Newfoundland in the east were compiled and compared, especially with respect to their  $\text{SO}_4$  concentrations. Late in the year an attempt was made to compare lake "loads" (lake concentration times runoff) with measured wet deposition as reported by Barrie and Sirois (1982). The comparison (Figure 3) shows good agreement in the fringe areas, where deposition is low. Lakes in the central region, from Algoma, Ontario, to Lac Laflamme in Quebec consistently show higher loads than indicated by measured wet deposition. The excess loads from the lake data may be a measure of dry deposition.

More recent data were received from Ontario Ministry of Natural Resources for the Algonquin lakes. These lakes, which had been showing small but consistent increases in  $\text{SO}_4$  concentrations from 1975 to 1979, in 1980 showed lower, and in 1981 sharply lower  $\text{SO}_4$  concentrations (Figure 4B). In response to the lower  $\text{SO}_4$  concentrations, the pH rose (Figure 4A). CANSAP data (Barrie and Sirois 1982) show similar, nationwide, lower loads in 1980 than in 1979. The reason for the trend reversal is not known at present. It might be due to shifting weather patterns or to reduced energy demand because of the economic recession. If the latter be the case, then economic recovery, though devoutly to be hoped for, will exacerbate the 'acid rain' problem.

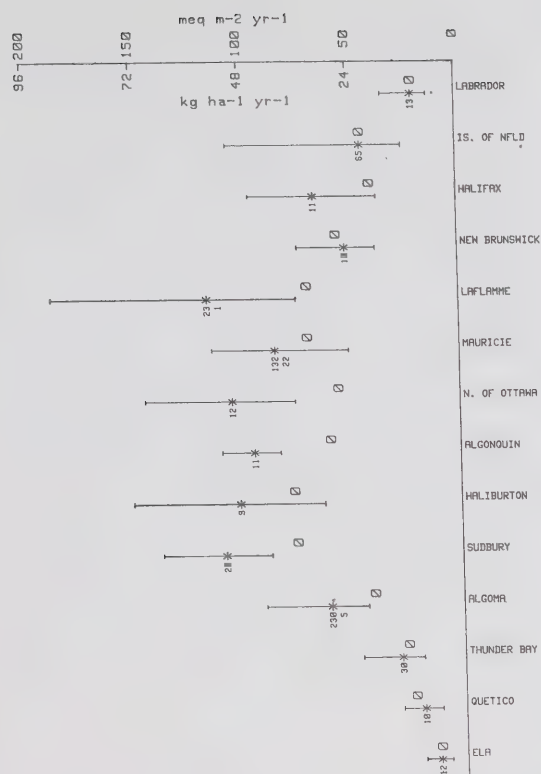


Figure 3.

Mean and range of SO<sub>4</sub> loads (\*) calculated from lake data, compared with measured wet deposition (Ø). The number beside the mean is the number of samples; where there are two numbers, the lower one is the number of lakes.

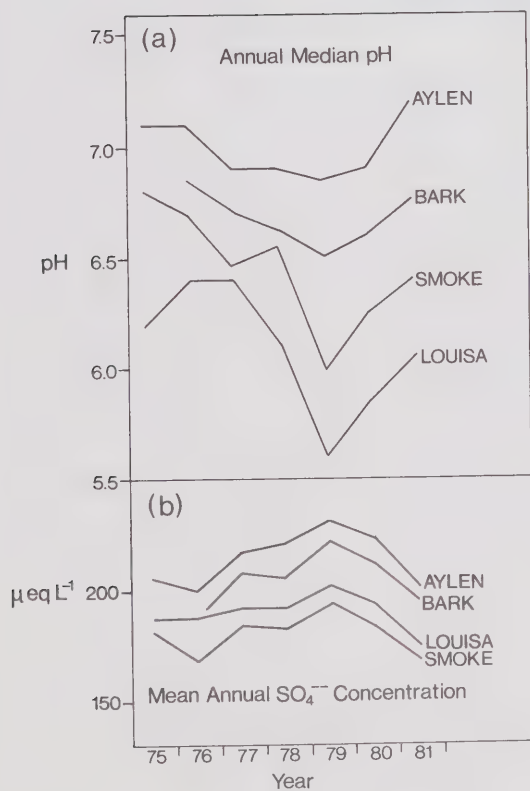


Figure 4.

Annual median pH and mean annual SO<sub>4</sub> concentrations in four Algonquin lakes.





**AQUATIC ECOLOGY DIVISION**





The Aquatic Ecology Division (AED) carries out field and laboratory experimental research on nutrient pathways, availability, dynamics and loading, algal and macrophyte ecology and physiology, lakes and wetlands ecology, paleoenvironmental history, and geochemical processes in eutrophic and acid lakes. It is involved in the solution of the problems associated with environmental degradation of recreational and the aesthetic value of Canadian waters and management of their quality.

The Aquatic Ecology Division is organized in three multidisciplinary sections: Nutrient Pathways, Great Lakes, and Ecological Impact.

### THE NUTRIENT PATHWAYS SECTION

The Nutrient Pathway Section concentrates on understanding the complex interrelated processes of nutrient availability and uptake, algal growth and decomposition, sedimentation, nutrient regeneration, dissolved organic substances, zooplankton grazing, and lake restoration methods.

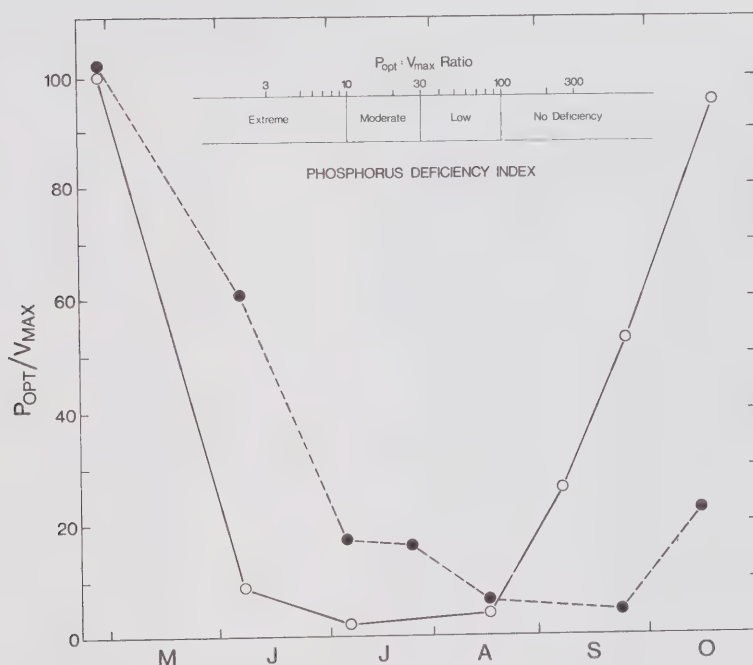


Figure 1. Phosphorus Deficiency Index for Lake Erie (Summer, 1979).  
[o] Central Basin, [•] Eastern Basin.

Work has continued on developing indices which will denote the physiological state of the lake plankton. The phosphorus deficiency index, i.e., the ratio of carbon photosynthetically fixed under optimum light to the maximum uptake of phosphate under enriched conditions (Fig. 1), was used to compare the relative nutrient deficiencies of the plankton. When the phosphorus deficiency index is applied to Lake Erie it is found that the Central Basin becomes deficient faster than the

Eastern Basin and by early June is nearing the extreme range. The P limitation in the Central Basin is relaxed in late August and the system becomes non P limited during September. In contrast, the Eastern Basin takes longer to become P limited but remains so during September and even into October. Research on the ratio of protein synthesis to carbon fixation may also provide a useful index of plankton nutrient deficiency. Measurements of the feeding and excretion rates of protozoans have been made and the potential of these animals to control phytoplankton and bacterial biomass in lake water has been assessed.

Research on the nitrogen cycle in lakes and streams has continued. The processes of nitrification ( $\text{NH}_4^+ \rightarrow \text{NO}_3^-$ ) and denitrification ( $\text{NO}_3^- \rightarrow \text{N}_2$ ) in lakes are being studied in cooperation with MacDonald College of McGill University. Why nitrate accumulates in some lakes but not in others remains poorly understood. Nitrification is also important in streams which have high ammonium concentrations, because unionized ammonia can be toxic to fish and benthic organisms. In conjunction with larval fish experiments (Environmental Contaminants Division) in a polluted stream, the unionized  $\text{NH}_4^+$  concentrations were found to be below the lethal level for rainbow trout. While ammonia may contribute to the overall toxicity of the stream, it cannot be the sole toxic agent.

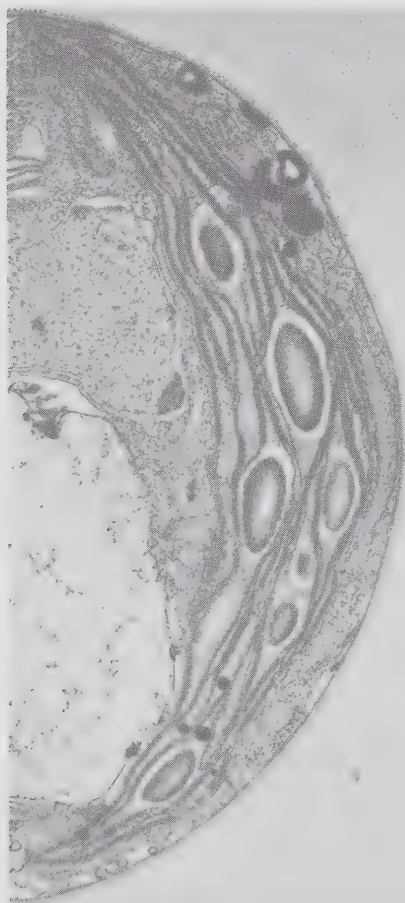


Figure 2.

Colloidal organic fibrils found in lake water. Fibrils surrounding a green algae.

One aspect of algal interaction is the competition for iron. Studies of iron mediated antibiosis in Black Lake, B.C., a naturally eutrophic lake, have been completed. Iron and algal chelators did influence the algal growth rate. Most of the field work was done with chelators isolated from algal cultures in the laboratory; however, one chelate was extracted from an Anabaena species isolated from Black Lake. This chelate stimulated the growth of Aphanizomenon flos-aquae, another blue-green algal species that blooms after the Anabaena bloom. Other observed interactions included suppression of bacteria and algal growth.

The presence of colloidal organic fibrils in the aquatic environment is increasingly recognized. They are produced by biota (Fig. 2) and appear to be multifunctional. Chemically, they are proteinaceous-carbohydrate polymers. Their significance in lake physiology has never been determined although their quantitative importance in a given lake has appeared to be considerable.

A physical isolation technique has been developed (Fig. 2A). The isolated colloids (Fig. 2B) account for 33% of the carbonaceous material which passes through a membrane filter. Chemical methods have been used to purify this material and the fractions are being studied for their ability to bind heavy metals and certain toxic substances.

ISOLATION OF COLLOIDAL FIBRILS FROM LAKE WATER

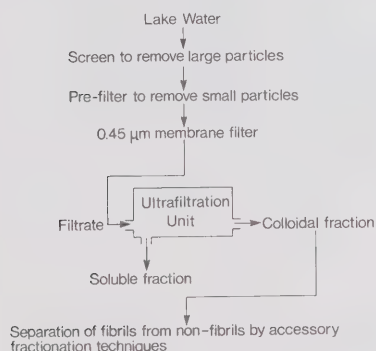


Figure 2A. Isolation scheme for fibrils.



Figure 2B. Isolated fibril fraction. Horizontal bar equal 0.5 microns.

## GREAT LAKES SECTION

The Great Lakes Section investigates and reports on biochemical processes affecting the Laurentian Great Lakes. The members of the section have worked mostly on Lakes Erie and Ontario in order to complement the major surveillance effort.



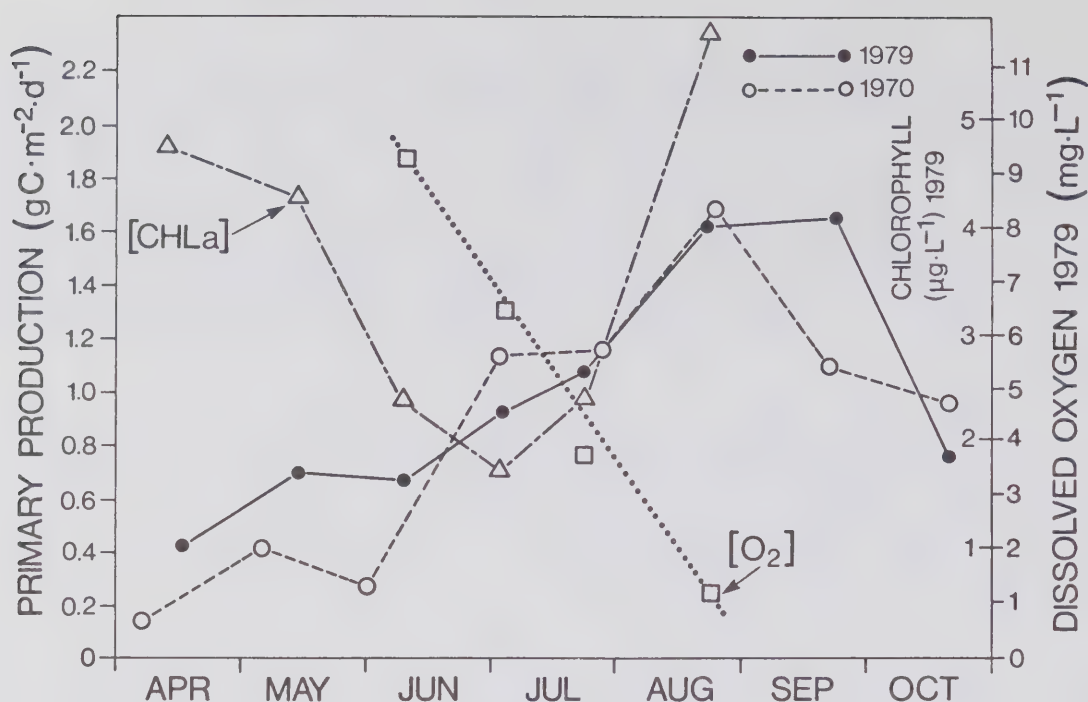


Figure 3. Comparison of primary production (1970, 1979) with chlorophyll (CHLa) and oxygen depletion in 1979.

Processes governing water quality, productivity, and dissolved oxygen have been studied in Lake Erie. A central theme to the phosphorus control program in Lake Erie is the expected improvement in hypolimnion oxygen levels. Organic matter is produced by algal primary production and consumed in the hypolimnion oxygen depletion process. Field work results from 1970 and 1979 (Fig. 3) show that there has been little difference in primary production rates. The difference between high and low oxygen depletion rates in the Central and Eastern Basins was found to be related to differences in the numbers of bacteria and the concentrations of chlorophyll and particulate organic carbon. These differences are thought to be caused by the dilution effect of the greater depth in the Eastern Basin.

Investigations continued into whether the historical information on oxygen depletion in Lake Erie justifies the conclusion that higher oxygen concentrations will result from nutrient loading controls. The results depend on analytical methods and are, as yet, equivocal. Benefits to general water quality seem to be occurring as expected from the nutrient control program.

A major effort has resulted in the preparation of a book entitled "Lake Erie: An Environment Under Impact." This book, to be published by Wiley-Interscience in 1982, is a study of Lake Erie's limnology and the perturbations caused by industrial and agricultural activities in the lake basin. The study concludes that Lake Erie can be restored and maintained in an acceptable state with moderate expenditures and careful decisions in the future.

Bioavailable phosphorus-iron compounds in sediments were studied using Mössbauer spectroscopy. These iron compounds were found to be fully saturated with respect to phosphorus and thereby unable to absorb any more phosphorus from the water. Sediments in some areas of Lake Ontario contain abnormally high amounts of phosphorus which may result from precipitation of an  $\text{Fe}^{3+}\text{-PO}_4^{3-}$  complex. Such a complex may represent an important sink for phosphorus.

Previously-gathered data on the trophic trends in the Great Lakes have been summarized in graphic form. Phosphorus has declined in the lower lakes (Fig. 4) but nitrate is now increasing rapidly (Fig. 5).

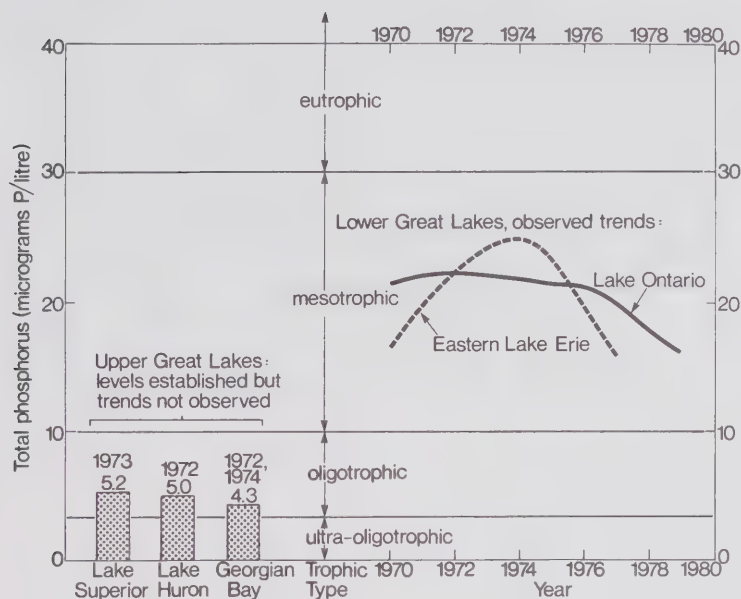


Figure 4.

Total phosphorus trends in the Great Lakes.

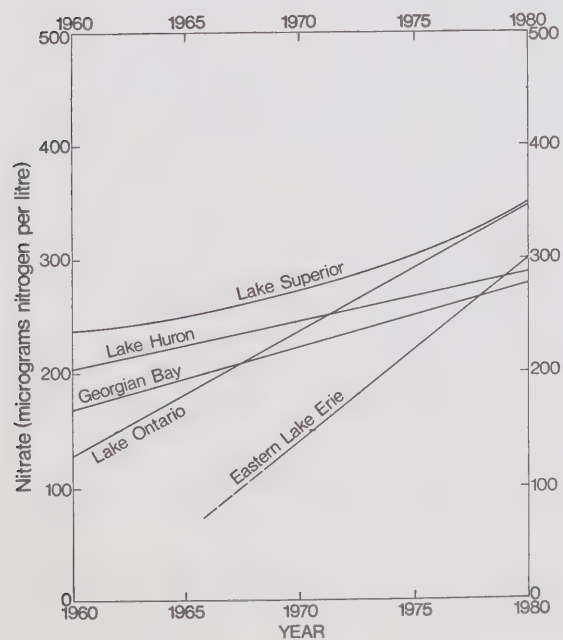


Figure 5. Trends of springtime nitrate in the Great Lakes.

A paleolimnological study was completed on the response of Lake Erie molluscs to variations in climate during the late Quaternary period (last 12,500 years). The data interpretation suggests that climatic changes were a driving mechanism of the ecological processes in Lake Erie's past. The report provides new information for understanding historic patterns and trends in natural eutrophication processes of Lake Erie, and demonstrates a close link between climate and Lake Erie productivity. Another study was completed on determining the length of time when low oxygen conditions have been present in the Central Basin of Lake Erie.

Lake Ontario studies were designed to investigate the linkage between eutrophication and contaminants. In cooperation with ECD and GLBL, sediment traps were used to study the fate of materials introduced by the Niagara River and distributed throughout the lake. Concurrent primary production experiments were conducted to determine whether algae aid the deposition of contaminants. The closer sediment traps were to the lake bottom the greater was the amount of material caught. This may indicate that the bottom is a source of resuspended particles. The presence of particles was studied with light transmission profiles of the water column at the regular surveillance stations in Lake Ontario during the last five months of 1981 (Figure 6). The August and September profiles showed three distinct layers; an upper section with reduced transmission due to increased productivity in the warmer

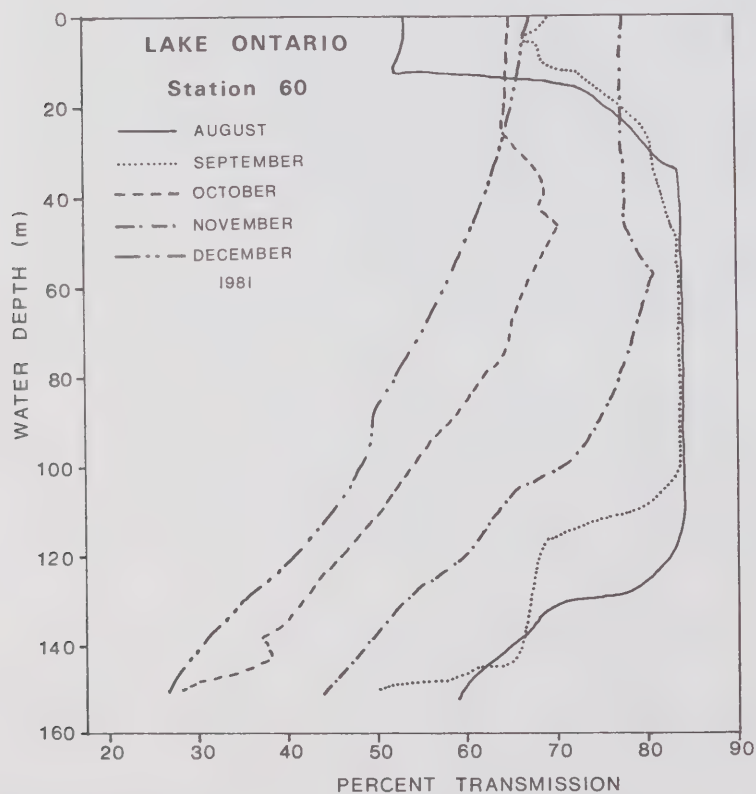


Figure 6. Seasonal changes in turbidity as measured by 25 cm path length light transmissometer in Lake Ontario, 1981.



epilimnion, a relatively clear mid-water column, and then a lower section with transmission decreasing towards the lake bottom. This lower section or nepheloid (cloudy) layer was detected lake-wide, at all stations with a water depth greater than 60 m. The average thickness in August and September was 22, 25 and 42 m for the offshore stations in the Western, Central and Eastern Basins, respectively. In the fall months, the light transmission decreased in the water column, and the nepheloid layer increased in thickness to 35, 65 and 100 m for the same offshore stations in the three basins.

A study of biogeochemical processes in Great Lakes sediments was begun in 1981. The goal of this interdisciplinary study is to relate biogeochemical changes recorded in Great Lakes sediments to recent environmental impacts and also to paleoenvironmental changes.

Sediments were sampled from selected locations in Lakes Ontario, Erie, Huron and Michigan. Long piston cores, gravity cores, and large volume box cores were subsampled. In addition, large volumes of surficial sediments were collected from 43 locations in Lake Ontario by box core for the DOE Sediment Bank. All of these samples are being preserved for long-term storage and subsequent analysis of environmental contaminants.

## ECOLOGICAL IMPACT SECTION

### Acid Rain Related Studies

Studies were carried out on sediments affected by acid rain from the Sudbury area. The nickel/copper ores at Sudbury average approximately  $35 \mu\text{g g}^{-1}$  selenium and  $8 \mu\text{g g}^{-1}$  arsenic. During the smelting processes, a fraction of the arsenic and selenium is transmitted to the surrounding ecosystems via atmospheric transport. Highly elevated levels of the two elements have been found in the suspended particulate matter in lakes near Sudbury. The rates of selenium and arsenic deposition into some of the lakes, as derived from the concentrations in dated sediments, are among the highest recorded anywhere in Canada, and show historical changes in the intensity of input of the two elements.

The study of heavy metal fluxes into remote, soft water lakes in the Algonquin area of Ontario has shown significant recent increases in atmospheric input. In spite of the low metal concentrations in the water column, the current depositional rate for potential pollutant metals Cd, Co, Cr, Cu, Ni, Pb and Zn exceed the contribution from national sources by 100 to 200%.

Determination of pH pattern of acid-susceptible lakes during the past thousand years was initiated using paleoenvironmental indices (diatom fossils).

Studies also continued on the effect of lake acidification on the cycling of organic matter in Precambrian Shield lakes. Extensive

field sampling in the Sudbury area and in Algonquin Provincial Park was carried out. Lakes affected to varying degrees by acidification were sampled in the spring after breakup, during summer stratification and in winter under ice conditions. Emphasis was on organic matter contained in the sediments and in suspended particulates.

Preliminary results indicate that branched and unsaturated fatty acids are likely candidates to serve as biochemical markers of ecological change in these lakes. Work is continuing on the other fractions in an effort to find supportive data.

Recent interest in the atmospheric deposition of trace metals into aquatic ecosystems has led to the development of several techniques of monitoring such possible contaminants. In order to alleviate problems with direct precipitation, vegetation sampling for elemental analyses has been done, with emphasis upon lower plants such as mosses and lichens. A study was carried out to determine: 1) the relationship between metal levels in bog mosses and higher vegetation such as shrubs and trees in such ecosystems; and, 2) the influence of the smelter complexes at Sudbury, Ontario, and Rouyn-Noranda, Quebec, on the metal content of bog vegetation. Bogs were chosen since chemical inputs to these ecosystems are strictly from atmospheric deposition.

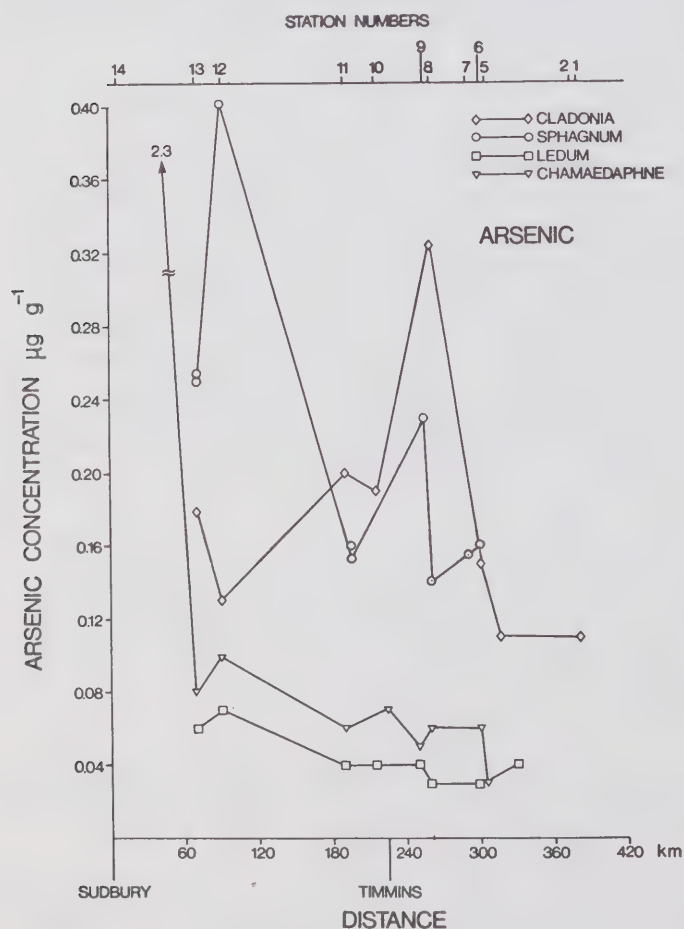


Figure 7. Arsenic control of plant tissue in relation to mining centres in northern Ontario. Note high levels from Sudbury and secondary source in Timmins, Ontario, and Rouyn-Noranda Area, Quebec.

Samples of bog vegetation, mainly Sphagnum moss and leaves of the higher plant Chamaedaphne calyculata (leather-leaf) were collected from 12 bogs along a 380 km transect from Sudbury, Ontario, and 100 km from Rouyn-Noranda, Quebec. Plant tissue was ashed and analyzed by atomic absorption spectrometry. In general, metal levels were higher in Sphagnum than in Chamaedaphne. Levels of the elements Cu, Cr, Pb, and Zn were highest near the smelters, dropping in concentration with distance. Major elements such as Na and K which are not emitted by the smelters showed no such trend. Potentially toxic As was also elevated near the smelters (Fig. 7).

The smelters also had an effect upon bog ecosystems. Local bogs had no living Sphagnum mosses, but higher plants including Picea mariana (black including spruce) and Chamaedaphne calyculata (leather-leaf) did not appear to be affected by smelter emissions, except for having elevated metal contents.

### Wetland Ecology

During the summer of 1980, field work was carried out on the salt marshes of Hudson Bay between the Ontario/Manitoba border and the Winisk, Ontario, area. A total of 14 sites were visited. In order to further understand the significance of Hudson Bay salt marshes for shorebird and waterfowl habitat, studies were carried out on the interactions between sediments, soils, and vegetation.

A study on Second Marsh (north shore of Lake Ontario at Oshawa, Ontario) was conducted to determine the distribution of the potential trace metal pollutants Cd, Cu, Ni, Pb and Zn in Second Marsh as evidenced by sedimentary concentrations. The study also examined the changes in trace metal concentration over the past century by analysis of four sediment cores.

Nickel levels were approximately three times higher than in other Lake Ontario marshes, while zinc levels from the marsh sediments were twice as high as in other Lake Ontario river mouths. Potential sources of metals include dumped dredge spoils, sewage treatment plant effluent, sewage sludge disposal and waste disposal sites.

### Aquatic Weeds (Macrophytes)

The aquatic macrophyte program is designed to evaluate the environmental impact of techniques available for aquatic weed control. Eurasian watermilfoil (Myriophyllum spicatum) is an exotic aquatic plant infesting many lakes in Canada. The distribution of milfoil and two other exotic weeds are illustrated in Fig. 8. Environment Canada has banned importation of Myriophyllum spicatum, Hydrilla, Egeria densa and Trapa natans. Unfortunately, Egeria has established itself in British Columbia and Trapa is located in the U.S. portion of Lake Champlain and advancing towards Quebec.



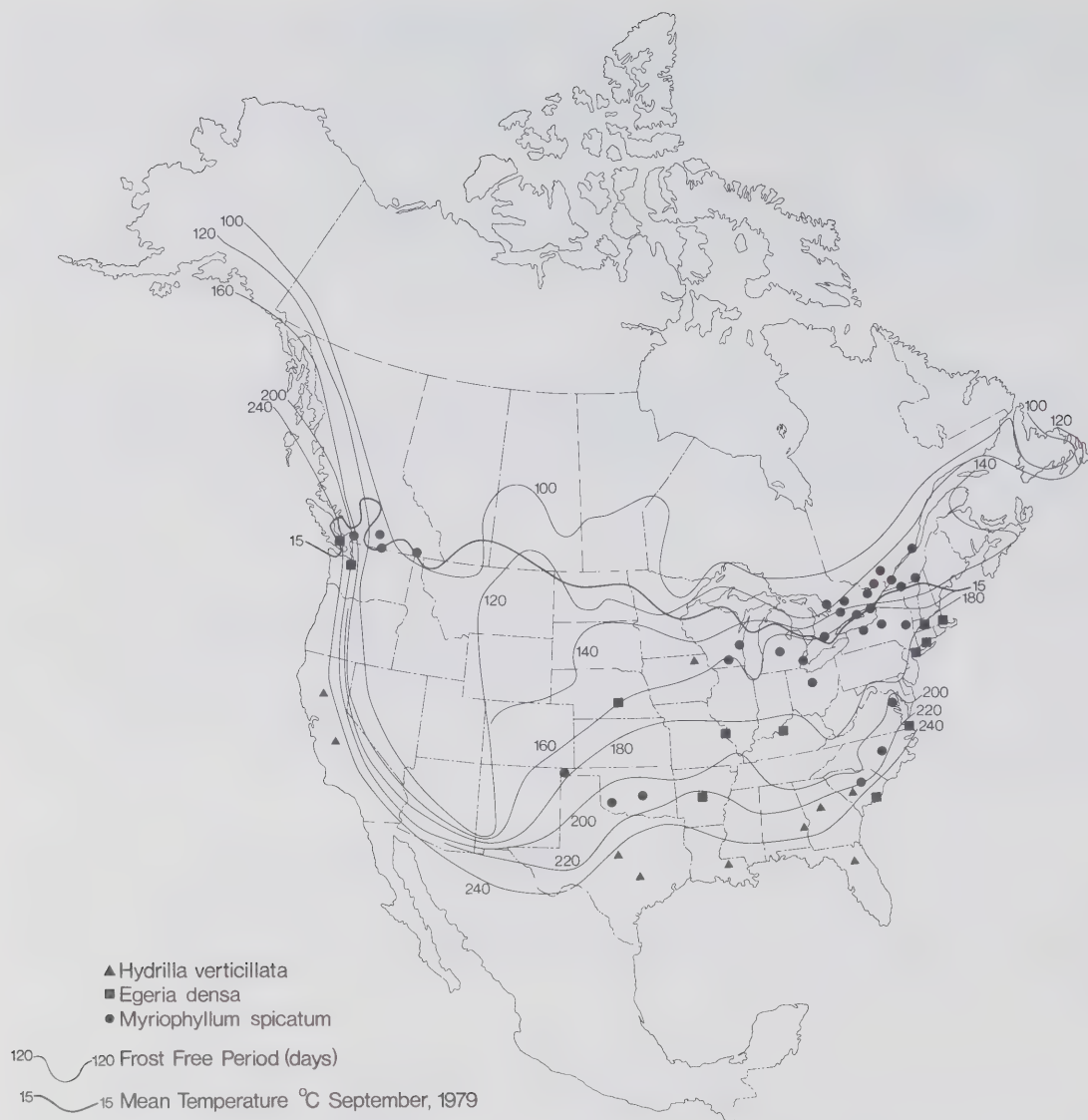


Figure 8. Distribution of *Myriophyllum spicatum*, *Egeria densa*, and *Hydrilla verticillata* in North America.

Eurasian watermilfoil control by mechanical harvesting exerts considerable demand on sediment phosphorus pools. The first year of a demonstration experiment on long-term control by mechanical harvesting has been completed. An attempt has been made to create a phosphorus-limited condition for milfoil by removing sediment phosphorus through mechanical harvesting.

Chemical control of Eurasian watermilfoil using 2,4-D was demonstrated to have minimum environmental impact. The nutrient release phenomena from milfoil killed by three herbicides (2,4-D, Diquat and Fluridone) was investigated. Diquat results in a rapid release of

nutrients but the community responds quickly to absorb the released nutrients. The herbicide 2,4-D results in nutrient release several weeks after application and the algal community is affected by the herbicide because nutrient absorption by the community is delayed for several weeks after peak nutrient concentrations appear. Fluridone results in nutrient release several months after application and the herbicide apparently also affects the algal community because no nutrient absorption occurred during the course of the experiment.

Aquatic macrophytes growing in acid lakes were observed to rapidly release nickel, zinc and copper into the water column. The release rates far exceeded atmospheric deposition rates.

The effect of aquatic macrophytes on sediment chemistry was investigated in some Quebec and Ontario lakes. Macrophytes were found to have a pronounced influence on the seasonal distribution of pore water nutrients, and their growth appeared to be limited by the rate of mineralization of sediment organic matter. In some sediments, intensive macrophyte growth induced hydrogen sulfide production and phosphorus precipitation as apatite-P.

### **Applied Statistics**

The statistical research was directed towards: 1) the study of the spatial and temporal variability of parameters measured in the surveillance program for the Great Lakes; 2) the determination of the relationship between environmental conditions and the presence of a species of shelled invertebrates; and, 3) the detection and estimation of abrupt change or trend in a sequence of observations, where methods presently cover river monitoring data and several types of measurements on sediment cores. The work in progress involves both the identification of available statistical techniques and the development of new techniques which are appropriate for the particular type of data collected in the study of bodies of water as well as the analysis of extensive data sets.





**HYDRAULICS DIVISION**



## DIVISIONAL OBJECTIVES AND ORGANIZATION

The Hydraulics Division undertakes research of natural phenomena related to the physical aspects of water and sediment.

For its objective, the Division has interpreted the general objective of the Inland Waters Directorate as:

"To advance, apply and communicate scientific and engineering knowledge and understanding of all aspects of the hydraulics of inland waters for the use of planners, engineers and managers of such resources throughout Canada."

In order to pursue this objective, the Division undertakes national programs in applied and basic research related to hydraulic, fluid mechanic, hydrologic, geophysics and geologic processes as they apply to fluvial, lacustrine and man-made environments.

The activities are:

- (i) To undertake - directly or by contract - applied and basic research into problems related to environmental processes, the optimum development of resources, the assessment of proposed changes in the environment and the protection of desirable environmental features.
- (ii) To develop mathematical models for descriptive and predictive purposes.
- (iii) To provide consultative services, information, technical reports, and expertise on environmental problems for government agencies, for the private sector, and for universities.
- (iv) To provide services in the calibration and testing of instruments for clients from government, private and university sectors.
- (v) To undertake - directly or indirectly - scientific and engineering investigations or studies of specific problems brought by clients within the Department of the Environment or other departments.
- (vi) To provide and encourage a stimulating environment and facilities for government and university researchers and to disseminate information and research reports and results through publications, seminars and conferences.

With the attachment of the Engineering Services Section to the Hydraulics Division, the goals have been extended to include the following:



- To invent, develop and improve instruments and systems for the efficient measurement of variables and the collection of samples in support of research programs in the field and in the laboratory for NWRI and other units of Environment Canada.
- To provide consultation and advice to scientists and engineers in CCIW, in other government agencies, in the private sector and in universities.
- To undertake and provide for the transfer of technology and also serve central agency programs such as PILP (Program for Industry Laboratory Projects).
- To provide technical services for:
  - the procurement of equipment and systems
  - the maintenance of equipment and instruments
  - the fabrication and repair of instruments and equipment
  - the drafting of illustrations
  - the storing of equipment, material and instruments.

These activities of the Hydraulics Division are shared by five operational Sections.

#### Engineering Services Section

The activities of the Engineering Services Section are delegated to three units.

The Instrument Research and Development Unit is charged with the responsibility of studying the characteristics of instruments, predicting their usefulness in a research situation, modifying or redesigning the instrument, developing a total system which may involve several instruments, evaluating the performance of the system and documenting the system for future reference.

The Equipment Research and Development Unit has the responsibility of studying the characteristics of apparatus and equipment used in research, consulting on their proposed application, modifying or redesigning the subsystem, and assembling, testing and documenting the final product.

The Instrument Calibration and Maintenance Laboratory is the main repository of measurement standard for NWRI.

#### Environmental Hydraulics Section

There are three main areas of research in the Environmental Hydraulics Section: open-channel hydraulics, river ice engineering and urban water resources. In open-channel hydraulics, the dynamics of

river flow, the mass and heat exchange as well as sediment transport processes are investigated. Development and improvement of models which can predict the mixing of effluents and the response of rivers to man-made changes are of prime concern. In river ice engineering, the mechanics of ice jams and their effects on flooding, the conveyance capacity of ice-covered rivers and the effects of frazil ice on the flow are the main questions which are being addressed. In the urban water resources area, emphasis is placed on the development and verification of models for urban runoff quantity and quality. The effects of urbanization on urban runoff and sources of pollutants in urban runoff are investigated in order to improve management and design of stormwater systems.

### **Office Services Section**

Office Services is a newly-created Section as of February 1982.

This Section serves all Sections and provides administrative support (clerical and financial) to the Divisional operations. Office Services manages the orderly production and distribution of reports and publications on scientific and engineering subjects, ensuring the communication of new information and knowledge to all sectors of society in Canada.

Office Services maintains a permanent file of research and technical reports. The Section responds to requests for reprints or copies of unpublished manuscripts; statistics on requests for reports are kept.

### **Shore Processes Section**

The work of the Shore Processes Section is concentrated in the areas of wind-generated waves and shore evolution. In wave research, fundamental questions of air/water interaction are addressed, such as the process of wave amplification and attenuation by wind. Shore evolution investigations are undertaken in several disciplines. Field studies include work on nearshore sediment transport and profile changes and on bluff failure. Erodibility of soils and the efficiency and design of low-cost shore protection are studied in the laboratory. Shore resources and geological influences are documented and examined by conducting surveys and by interpretation of nearshore sediments, primarily in the Great Lakes. In addition, there is active technology transfer. In this latter category of work, such things as coastal engineering studies are undertaken for clients under the cost recovery policy and site-specific reports on nearshore sediments are prepared in response to requests.

### **Technical Services Section**

This Section operates the National Calibration Service which calibrates current meters from across Canada for agencies in the private, university and public sectors.

Support is also provided to clients from other units of government or the private sector who are undertaking tests of equipment or research work in the laboratories.

In addition to the above, the Section also provides the following services:

- (i) Operating the light metal and woodworking shops.
- (ii) Maintaining and installing electronic equipment.
- (iii) Scheduling and assigning technical staff in support of research studies.
- (iv) Maintaining the hydraulic and geotechnical laboratories and their equipment.

### ENGINEERING SERVICES SECTION

#### Pacific and Yukon Lightweight Profiler

The Pacific and Yukon Region of NWRI required a highly advanced system to survey the water quality of lakes and estuaries in the Region. The system (Fig. 1) had to be used from small boats, transportable, lightweight and self-powered. The surveying is done in a vertical profiling mode, while data on temperature, salinity, conductivity, turbidity, fluorescence and depth are logged and displayed simultaneously. Three major subsystems include the winch and power pack, the calculator and logger, and a modified Guildline, salinity-temperature-depth sonde.

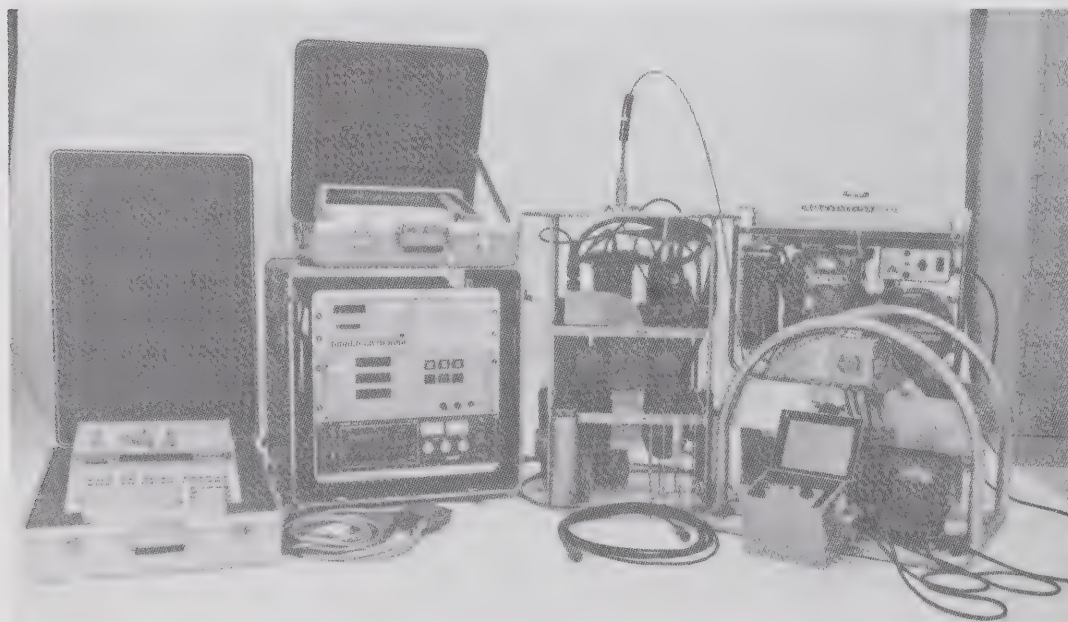


Figure 1. Pacific and Yukon lightweight profiler.



## Frazil Ice Sensor Investigation

Laboratory tests and a progress report were completed on a frazil ice sensor. The sensor is based on water conductivity measurements for an indication of frazil ice content. After adapting a high-quality Guildline salinometer and designing an appropriate conductivity cell which includes a deicing system, repeatable laboratory results were obtained to show that frazil ice content can be related to conductivity measurements. The sensitivity of the instrument is dependent upon the water's nominal conductivity. This confirms the theoretical model developed earlier.

## Orbitals and Current Meters

A study of the adverse effects of waves on imperfect current meters was completed and a report issued. It is entitled: "Current Meters, the Effects of Unsymmetrical Response When Operating in Waves." The main conclusion is that the unsymmetrical polar responses of current meters has a major effect on their threshold speeds when they operate in wave zones (Fig. 2). More care in measuring this characteristic must be taken in estimating the threshold of current meters used in NWRI. The investigation and report were submitted.

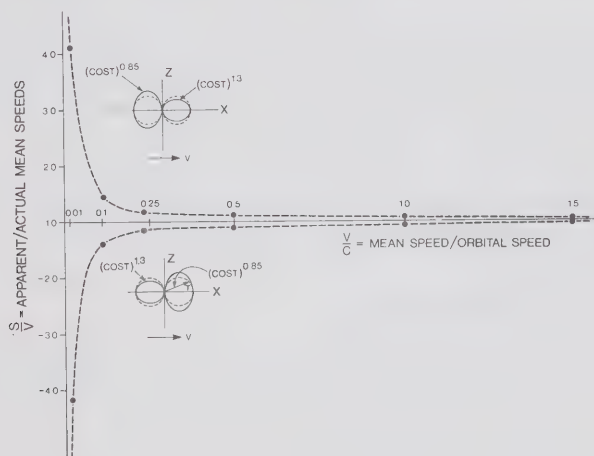


Figure 2. Graph of speed ratios for a current meter having unsymmetrical left and right half planes.

## Automated Multiwavelength Identification Scanner

The automated multiwavelength identification scanner is an electronic addition to the 10-15 year old Perkin-Elmer Spectrometer. This scanner enables the optically good existing instrument to become automated and more versatile. It is now able to process eight steps in single and 25 steps in synchro mode of operation.

Both modes of operation lead to very flexible analysis of the compounds by being able to scan the excitation and emission frequencies from 200 to 800 nm under the control of a computerized scanner.

### **Shipboard Radiometer System**

An eight-channel, satellite-compatible shipboard radiometer system intended to measure the volume-reflectance of lake-water in several spectral bands was engineered during the year. This system detects optical radiation levels in the same four spectral channels (nominally blue; green; red; infrared) as used for the Multi-Spectral scanner of the LANDSAT (formerly ERTS) orbiting satellite. The spectral behaviour of volume-reflectance is a parameter required for correct analytical interpretation of lake-imagery produced by such satellite remote-sensing.

The system (comprising splash-proof radiometric-cannisters, cables, special boom, and onboard electronics) is transportable and can be readily installed on any of CCIW's monitoring or research vessels. It can be simply stowed inboard when not in use or at night.

### **Recorder Chart Drive Refurbishment**

Maintenance problems have plagued the H.P. 7100 field recorder chart drives for years. These electrowrite recorders are used in the field for long-term, continuous recording of various meteorological parameters.

Investigation showed that the use of the recorder at one chart speed for long periods of time caused the drive systems to be in a poor condition. Extensive refurbishments were carried out on the drive systems.

The recorders were also completely overhauled and special attention was paid to the servomotor clutch systems.

### **Wind Direction Compass Replacement**

Because of increasing maintenance problems with the Plessey MOQOC clamping compasses used in the meteorological buoy MK I sensors, it was decided to replace them with the Aanderaa 1248 compass. It was electrically compatible and required only a few mechanical changes to the sensor head to allow mounting. All units were modified for the '81 field year. It was noted that no sensors were returned because of compass failure during the following season.

### **Wave Forces Subsystem**

A small system was assembled to log wave height, tethered buoy orientation, and tether cable tension. The system used a Datawell buoy/receiver, digiquartz compass, custom load cell and Sea-Data logger.

Under control of the timer in the Datawell receiver, the system logged data twice per second for 20 minutes every three hours.

Analysis of the data from the system provided the correlation between ambient wave height and axial loading in the cable.

### The Shipboard Data Acquisition System (SDAS)

A micro-computer system, based on a Hewlett-Packard model 85 computer, was developed to handle the acquisition and logging of data from a three-channel Technicon auto-analyzer system for chemical analyses.

The system allowed the operator to choose one of seven major functions from a menu. These were:

- 1) Initialize a cruise
- 2) Create a new tray pattern
- 3) Edit a tray pattern
- 4) Begin a run
- 5) Print a report
- 6) Transfer data to the main data bank
- 7) Edit raw data.

The operator was prompted at each stage of the process, and any data which could be updated automatically were updated. This system is routinely used on surveillance cruises.

### Solar Screen Study

As one element of a wide-ranging energy conservation program at CCIW, solar radiation screens have been installed on selected windows of the building. Would the screens reflect more incoming solar radiation than heat saved through reduced convective heat flow out from the screens? This question was addressed in the solar screen study.

A set of measurements was made on a side-by-side installation of screened and unscreened windows. From these data, an estimate of the heat flow per unit area through the windows was made. This information was then used as a base for an extrapolation to estimate total energy difference (screen window loss - clear window loss) over a winter period - November 1 to April 30.

Results of this work have been released in an unpublished report ES-522.

### Small Wind Tunnel Improvements

A scientific study to measure air motion over simulated water waves was thwarted by inadequacies of the original wind tunnel. The tunnel had excessive air turbulence, too low a range of air flow, and excessively high mechanical vibrations which upset the pressure sensors used to make the readings. An analysis of the system resulted in a redesign of the wind tunnel. The redesign involved an improved, higher



power, variable-speed motor/fan combination; aerodynamically/mechanically improved transition duct; addition of suitable baffles; isolation of the ducting from the motor/fan by mounting on separate beds; using selected mechanical vibration isolators; and the addition of mechanically isolated mounting pads for the pressure transducers.

### **Soil Erodibility Instrument**

The need arose to measure the erodibility by water of various cohesive sediments such as those found on bluffs, and to correlate these data with the results from other geotechnical tests. Because of the scientific uncertainty as to how to determine erodibility of these materials, a probable best method was established and laboratory bread board apparatus was designed to prove the method.

A finalized version of the above apparatus will be prepared and reported upon at a later date.

### **Sediment Resuspension Collectors**

In order to study nutrient loadings and sediment movements in the Great Lakes, it is vital to know the amount of bottom material which is put back into suspension by bottom currents and wave action. To assist in this study, sediment collecting apparatus was designed and built for lowering onto the lake bottom. The apparatus consists of an aluminum tetrahedral frame upon which is mounted a number of sediment collecting tubes at different levels. Above the frame is a special subsurface float and mooring line to which are attached more sediment tubes at different levels. All tubes have a length to diameter ratio of 16:1 which has been found by experiment to prohibit resuspension of collected sediment. To avoid contamination of the samplers during deployment, all tubes are first filled with filtered water and caps are placed on all the tubes which are mounted on the tetrahedral frame. After the system has been placed on the lake bottom and the mud cloud has settled, the caps on the lower 12 tubes are pulled off in sequence by a special draw pull. Normally the sampler would be installed for five to 25 days depending upon the amount of precipitate anticipated at each site.

### **Natural Convection Tank**

This tank is used for the laboratory simulation of the circulation and heat transfer associated with a thermal bar which occurs naturally in a body of water. The fibreglass tank has three compartments side by side but the adjoining walls are of thick aluminum plate to give good temperature distribution, and the front face of the centre (working) compartment has clear polycarbonate for occasional viewing. The entire tank is heavily insulated and located in a temperature controlled cold room to ensure minimal heat losses. One side tank has water continuously passing through it from a constant temperature water bath, while the other side tank has an immersion cooler. With this

ability to heat and cool the water in the side tanks, the conditions necessary for a thermal bar can be set up.

### **Through-the-Ice Water Sampler**

The Ocean Science and Surveys field parties in the Arctic required a supply of water sampling bottles suitable for sampling through ice cover. These bottles were to be small in diameter, free of external appendages, and transportable by helicopter, aircraft or tracked vehicle. The resulting sampler consists of a commercially-available, stainless-steel cylinder, sealed at each end with a plug valve. In operation, a quantity of cylinders are evacuated at the field camp and supplied to the field site where they are inserted in a mooring line and passed down through a hole in the ice. Triggering of each sampler is done by the serial dropping of mechanical messengers down the mooring line. The falling messengers open the upper valve of each bottle allowing sample water to fill the bottles. Upon retrieval, the bottles can be drained by opening the lower valves and the bottles recycled for the next mooring.

### **Core Extruder (Self-Contained)**

The accurate sectioning of lake bottom cores for analysis has previously been done with the aid of a mechanical (screw) type core extruder or by an extruder using tap water. Both extruders have inherent deficiencies which have been overcome by a new, self-contained, hydraulic core extruder which has a specially-designed, foot-operated pump and a simple container for the water supply.

The extruder consists of a light-weight stand to which either Benthos or the light-weight corer's core tubes can be mounted. Extrusion is done hydraulically, using the foot-operated pump, a small container of relatively clean water and a free piston which has been inserted into the base of the core tube. Quick-connect fittings are used so that the system can be easily dismantled in the field and placed in a metal box for transporting.

### **Peeper Deoxygenation Apparatus**

Several field studies are underway in which interstitial water samplers (Peepers) are inserted into the lake sediment to determine the concentration of different species of aquatic macrophytes in the pore water. Some of these species such as sulphides or manganese, would be oxidized by the presence of dissolved oxygen within the Peeper itself, giving rise to erroneous analyses. Special chambers were therefore required for de-oxygenation of the Peepers prior to deployment. Each chamber, which holds two Peepers, is made of transparent polycarbonate and has a sealed lid which is held down by a single clamp. In each lid is a quick-connect gas outlet fitting, a needle valve and a pressure relief valve. The chambers have a quick-connect gas inlet fitting at the bottom. All chambers are filled with distilled water. The chambers

are connected by tubing in a series (cascade) so that a supply of dry nitrogen can bubble from bottom to top of all chambers in sequence with the bubbles passing over the active surface of each Peeper. After the bubbling period is complete, the end chamber can be removed from the series by closing the needle valve and removing the gas supply tubing. A special support stand for the chambers has been supplied.

### Wildlife Embryo Sensor

The feasibility of detecting life within a turkey egg shell at the 12th day of incubation has been demonstrated for Canadian Wildlife Service. Normal candling techniques do not work on some eggs because the shells are too opaque. Using a piezoelectric crystal, with the egg placed on top, the slightest motion of the egg can be detected as the embryo moves inside. Isolation from building motion and seismic interference was a major part of the design challenge. This was met by a light-weight, elastic suspension system and active filtering of the signal. An audio signal also helps the user detect the motion signal that can be buried in the noise. The wildlife embryo sensor is used to study the survival rate of seagull embryos in situ.

### Wave Direction Buoy Modifications

The CCIW Wave Direction Buoy was modified and readied for participation in the Atlantic Remote Sensing Land Ocean Experiment, ARSLOE.

The main modifications were: a) rechargeable battery can, b) battery charging by solar energy: c) recording period controlled by wind speed, d) dual transport sea data cassette recorder; and e) monitoring test point facilities.

The buoy records data (roll, pitch, heave, surge, sway, compass, anemometer and wind direction) every hour for approximately 30 minutes if, during the three minutes following the hour, the wind speed is higher than the preselected wind speed threshold; otherwise the buoy records data every 6th hour for 30 minutes.

### Turbidostat

Cultivation of microorganisms in liquid suspensions is a basic technique in many types of physiological, biochemical, microbiological and biophysical investigations. Controlling the conditions for growth, whatever microorganism to be cultivated, is of great importance to achieve acceptable and reproducible results.

The turbidostat is an optical density measuring device which maintains a growing culture of algae cells at a specific cell density by periodically adding a diluting medium (nutrient) to the algae culture vessel. An optical sensor, immersed in the algae culture, measures the



algae cell density. The controller activates the valve when the cell density becomes higher than the selected value. The culture is then diluted to the required cell density.

### **Extended Depth Multiband-Transmittance Sensor**

The operational depth of the multiband-transmittance temperature profiler was increased from 100 to 250 m. This modification enables the instrument to sense the nepheloid layer in Lake Ontario. Also to improve maintainability, new temperature and pressure sensors were mounted in the same submersible package as the transmittance sensor. A new profiling cable with improved resistance to fatigue was substituted. The lamp condensor in the transmittance sensor was redesigned in order to reduce sensitivity to vibration and shock. The sonde was deployed on all Lake Ontario cruises after July 1981 with satisfactory results according to the users.

### **CATTS Modifications**

The two CATTS (Current and Temperature/Transmittance System) systems have been in use in various configurations since 1976. Each system has been used with different types of electromagnetic current meters, sometimes with a "turbidity" sensor and sometimes without. It was evident, even though chemical anti-fouling schemes were used, that mechanical action had to be used to clean optical surfaces on the "turbidity" sensor. The windows of a small transmittance sensor were cleaned periodically with kitchen cleaning pads attached to an air piston that was driven by a solenoid valve from a SCUBA air tank. A fluxgate compass was also incorporated to determine if there were accidental variations of the platform orientation on the lake bottom. Some modifications were made to improve datalogger capability. Also, the entire system was towed in the NWRI Hydraulics tow tank to determine the effects of the layout on current meter sensitivity. Each system was deployed in the field, one system for 30 days and one for 90 days.

### **Image Processing Interface or Video Digitizing System (VIDS)**

Modifications to the Norpak computer display system used by the Environmental Spectro-Optics Section of the Aquatic Physics and Systems Division were done to allow measurement of film density (using the video camera portion of the Norpak system). A versatile film transport was designed to allow film densitometry or digitization for film formats varying from Super 8 to 230 mm x 230 mm aerial film size. An illumination system was designed, and modifications to camera optics and electronics were made.

### **Zeeman Atomic Absorption Spectrometer Furnace Temperature Measurement**

A consultation report on the feasibility of measuring the temperature of the interior and exterior of the graphite furnace in a

spectrometer, used by the Environmental Contaminants Division, was prepared. A review of possible optical methods, relative merits, commercial equipment, calibration methods, and potential errors was done and a Technical Note was written.

## ENVIRONMENTAL HYDRAULICS SECTION

### Field Measurements of Transverse Mixing

Results obtained from dispersion experiments conducted at five different river reaches were analysed. Transverse mixing coefficients were obtained by matching the data with a simulation model. The results indicated that the sinuosity of a stream is a very important factor in determining the value of the transverse mixing coefficient. A report has been written.

### Flow Under Ice Cover

The velocity distribution under floating covers has been investigated using a turbulence model. The results were used to review standard stream gauging techniques. Changes in suspended sediment concentration distributions caused by ice covers have also been investigated.

### Verification of a Turbulent Flow Model

Laboratory experiments to verify a turbulent flow model based on the  $k-\epsilon$  turbulence model were completed. Flows with free surface and with top covers were tested. In the latter case, both natural ice cover and artificial covers with different roughnesses were used. Comparisons between the measured and predicted distributions of longitudinal velocity component and the turbulent shear stress were made. Figure 3a shows typical comparisons for the free surface flows while Figure 3b shows the same for the flows with top covers. The velocity and shear stress measurements were carried out using a Laser Doppler anemometer.

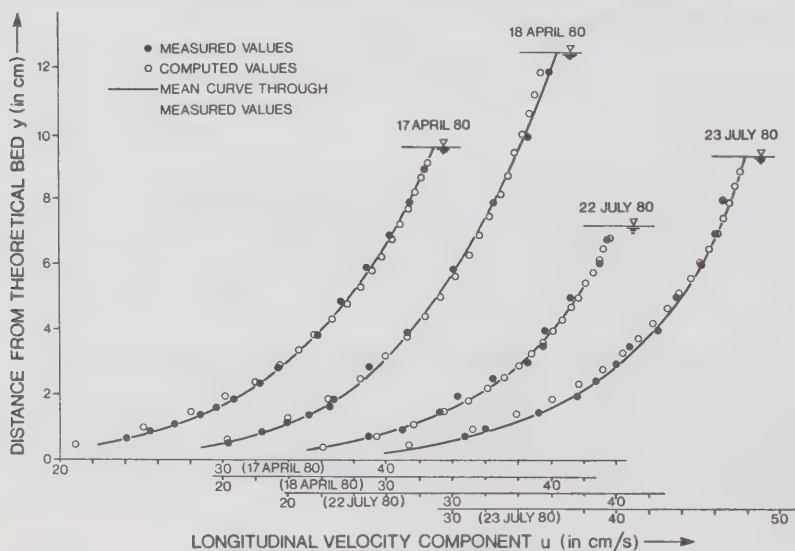


Figure 3a.  
Comparison of  
predicted velocity  
with measurement.

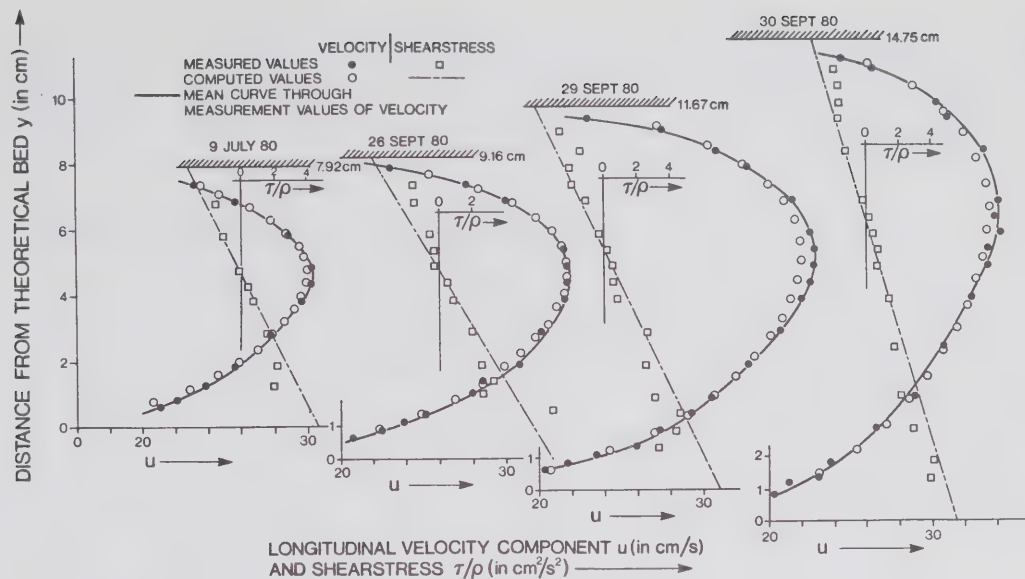


Figure 3b. Comparison of predicted velocity and shear stress with measurement.

### Investigations of Mixing Using Turbulence Model

To investigate the effects of width-to-depth ratio on the turbulent mixing characteristics of a channel flow, a three-dimensional turbulent flow model was developed based on the method proposed by Patankar and Spalding. The model is capable of predicting the secondary circulation in the transverse plane which contributes to dispersive transport.

### Application of MOBED to Lesser Slave River in Alberta

The unsteady, mobile boundary flow model MOBED has been modified to supply input data to the model in the HEC-2 format. This revised model is being applied to the Lesser Slave River in Alberta to predict the effect of meander recently implemented cut-offs on the regime of the river.

### Calibration of Bed Load Samplers

Experiments were continued in a sediment flume to assess the relative effects of sediment particle size and sampler size. The results have shown that when  $L_s/D_{50} = 65$  ( $L_s$  = sample length,  $D_{50}$  = median grain size), the efficiency of the basket sampler used by the Water Survey of Canada can be defined by the relationship

$$E = f \left[ \frac{t_* U_*}{L_s} \right]$$

in which  $E$  = sampling efficiency,  $t_*$  = time to collect one sample,  $U_*$  = shear velocity. This study was conducted to provide information



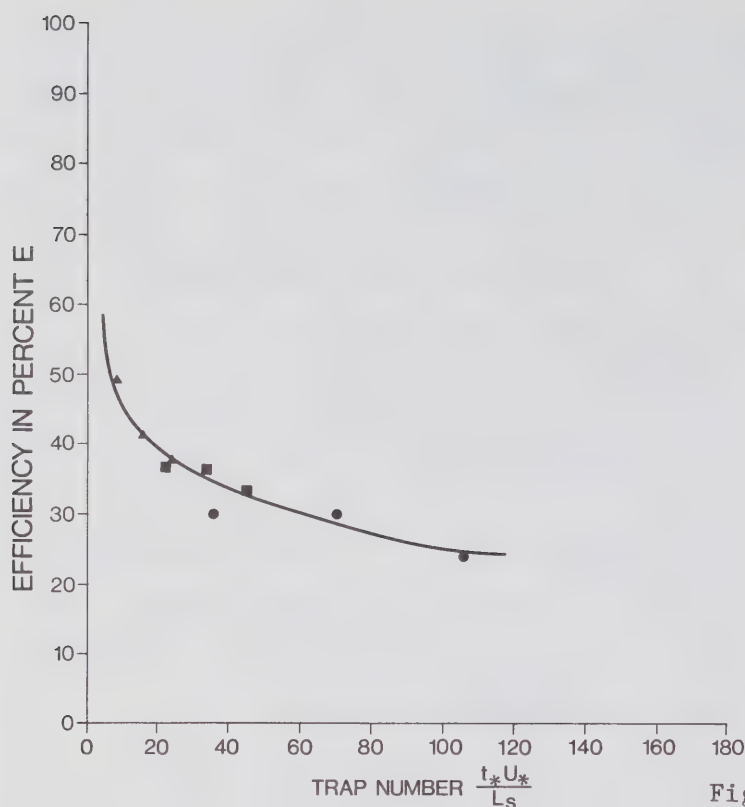


Figure 4. Variation of efficiency with trap number.

for the Water Survey of Canada. The recommended calibration curve for this sampler is shown in Figure 4.

#### Sensitivity of the Price Current Meter to the Effects of Frazil Ice

During the winter months, flow measurements have to be made through an ice cover. Under this condition a current meter quite often has to pass through a layer of frazil (slush) ice immediately below the ice surface before it reaches the flow of clear water. The Water Survey of Canada is concerned that under such conditions the cups of the Price meter may be filled with slush ice, thereby affecting the clear water calibration.

Theoretical analysis showed that the meter response is very sensitive to changes in the geometry of the rotor cups by partially or completely filling them. Tests simulating level-full cups were carried out and the results indicate a maximum reduction in the rate of rotation of the rotor of about eight percent. The overall difference in the meter response for open and filled cups can be seen.

#### Field Studies of River Ice Jams and Flooding

This is a long-term observation program, initiated in 1979. Emphasis is on collection of quantitative data needed to address

deterministic and statistical aspects of river ice breakup and jamming. This year, breakup will be documented for the third time in the lower Thames River and for the second time in the upper Grand River. Contact and cooperation with other agencies interested in jamming problems has been maintained and expanded.

### Analysis of Historical Ice Breakup Data

An attempt is being made to determine whether useful information on ice breakup can be extracted from the water level records of hydrometric gauges operated by the Water Survey of Canada. Preliminary analysis has shown that these records are a valuable source of historical data. The data analysed so far have led to development of a conceptual model of the breakup process. This model showed that the water level required to initiate breakup and the maximum breakup stage increase with freezeup stage and ice thickness but decrease with channel width. The effects of thermal deterioration of the ice cover prior to breakup have yet to be investigated. This study is carried out in cooperation with the Guelph office of the Water Survey of Canada.

### Theoretical and Laboratory Studies of River Ice Jams

The existing theories of floating equilibrium jams differ in their predictions of the water stages caused by the jams. This is due to the use of different and often arbitrary methods to compute the flow depth under the jam. The theory has been applied in conjunction with hydraulic resistance considerations to develop a convenient dimensionless expression that can be tested in terms of measurable ice jam characteristics. The average line drawn in Figure 5 provides a simple means to determine the jam stage in terms of channel width, slope and discharge.

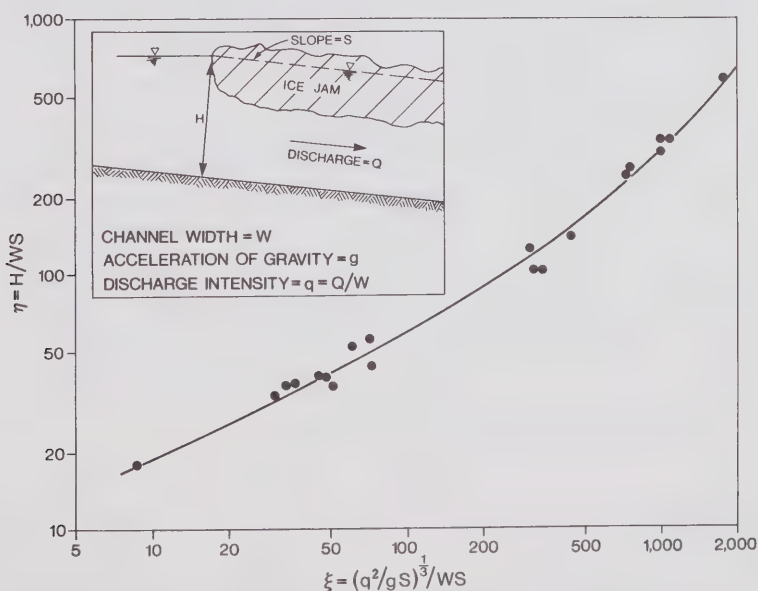


Figure 5. Dimensionless jam stage versus dimensionless discharge for a floating equilibrium jam in a wide channel.

A well-known and often fearsome event during breakup is the surging ice run that follows the release of a major ice jam. Analysis has shown that approximate surge calculations may be carried out by adapting existing models of unsteady open-channel flow. However, it is not known how to handle situations where an ice run is arrested and a new jam begins to form. The main unknown is the downstream boundary condition, i.e. flow depth and discharge at the point of the new jam. To investigate this problem, a laboratory study has been initiated.

### **Improved Design of Road and Bridge Deck Drainage**

Under the sponsorship of the Ontario Ministry of Transportation and Communications, the Hydraulics Division conducted a hydraulic study of road and bridge deck drainage. Using experimental data from an earlier phase of the study, a new procedure for the design of bridge deck drainage was developed. This design concept regards the flow on the surface as an open-channel flow which reaches a certain design width at peak runoff. A final report summarizing experimental results and design procedures for road drainage inlets and bridge deck drains was completed and submitted to the Ministry.

### **Waterford River Basin Study**

Urban development in the Waterford River Basin in Newfoundland caused a number of water resource problems including flooding and deterioration of water quality in the Waterford River. To find remedies to these problems, an urban hydrology study of the basin was initiated. The study is conducted jointly by three government agencies - Newfoundland Environment, Inland Waters Directorate (DOE) Atlantic Region and the Hydraulics Division of NWRI. The main work activities in the fiscal year 1981/82 included the collection of catchment data for hydrological modelling and monitoring of streamflows and water quality.

### **Rideau River Stormwater Management Study**

Progressive deterioration of water quality in the Rideau River in Ontario has been linked to urban and agricultural runoff. To find remedies to this problem, the Rideau River Stormwater Management Study was initiated. The Hydraulics Division was invited to participate in the study, primarily in an advisory capacity. Contributions were made to a recently-completed contract study of the pollution control effectiveness of a stormwater impoundment. The study report is presently under review.

### **Persistent Toxic Substances in Urban Runoff**

As a follow-up to an earlier pilot study, the investigations of persistent toxic substances in urban runoff were extended to ten cities in Southern Ontario. Over 70 composite samples from these locations were submitted to the Water Quality Branch (IWD) to be analysed for heavy metals, PCBs, organochlorine pesticides,



organochlorine biphenyls, polyaromatic hydrocarbons and other compounds. Analytical results (not yet available) will be used to establish loading rates and annual loads of persistent toxic substances in urban runoff.

#### **Adaptation of the ILLUDAS Model to a Desk-Top Computer**

The standard version of the ILLUDAS (the Illinois Urban Drainage Area Simulator) model written for the IBM 360/75 computer was modified and adapted to a Hewlett-Packard 9830 desk-top computer. The modified model was verified on a test catchment and subjected to a sensitivity analysis. As reported in the final report, for a small catchment with simple flow routing, the modified model performed as well as conventional models requiring large computer systems.

#### **Effects of Urban Land Use on Runoff Quantity and Quality**

Characteristics of urban runoff were investigated in two test catchments with commercial and industrial land use, respectively. A large number of rainfall/runoff events were monitored in both catchments and the observed data were partly analysed. A progress report will be prepared as soon as the chemical analysis of collected samples is completed.

#### **UNESCO Manuals on Drainage of Urban Areas**

Under the International Hydrological Programme, UNESCO (United Nations Educational Scientific and Cultural Organization) initiated a project dealing with the dissemination of knowledge on urban hydrology. One of the project objectives is to prepare two manuals on Collection of Urban Hydrological Data and on Drainage Design in Urban Areas. The Hydraulics Division was invited to participate in this activity by preparing several chapters for these manuals. First drafts of chapters dealing with the collection of hydrological data, organization and administration of data collection programs, and hydraulic design of drainage elements were submitted to UNESCO for review.

#### **Sewer Junction Study**

The second phase of the sewer junction study is underway. This phase of study deals with energy losses at junctions with inflow from a lateral. A plan was prepared to conduct the study of energy losses for a range of pipe diameters and selected junction geometries. One third of the planned test runs have been completed.

#### **Variation of Rainwater Quality**

In conjunction with the study of the effects of urban land use on runoff quality, a study on the variation of rainwater quality was conducted in a light industrial catchment during the 1981 field season. A newly developed sequential rainwater sampler was used to

collect sequential rainwater samples for chemical constituent analysis. Using the variation of rain quality results, the concentration load derived from storm surface runoff can be accounted for.

## SHORE PROCESSES SECTION

### Nearshore Sediment Transport

For several years data on nearshore suspended sediment, waves and currents have been collected at a site in Lake Ontario, using the SOLIDS (Study of Littoral Drift in Suspension) sled and fixed transducers. In the past year emphasis has been placed on evaluation and analysis of these data to examine relationships between the suspended sediment flux and wave energy.

Several interesting general comparisons can be made with other experiments to measure nearshore sediment transport reported in the literature. Although most other work has been done on ocean beaches, our experiments in Lake Ontario were conducted under some of the most severe wave conditions of any. The waves tended to be steeper, reflecting the fact that they were all locally generated storm waves in contrast to some cases where ocean swell were the dominant waves. Measured suspended sediment concentrations were of similar magnitude but, because the waves approached the beach nearly normally, longshore transport rates were somewhat smaller but of the same order of magnitude as reported by others. A paper describing the results will be completed early in the next fiscal year.

### ARSLOE

Wave data collected with the Motion Package Buoy at the Atlantic Remote Sensing Land Ocean Experiment off Duck, North Carolina were processed during the year. Some 250 thirty-minute runs were analysed to produce the Fourier coefficients of the directional wave spectra, mean wave direction, and mean wind speed and direction. The

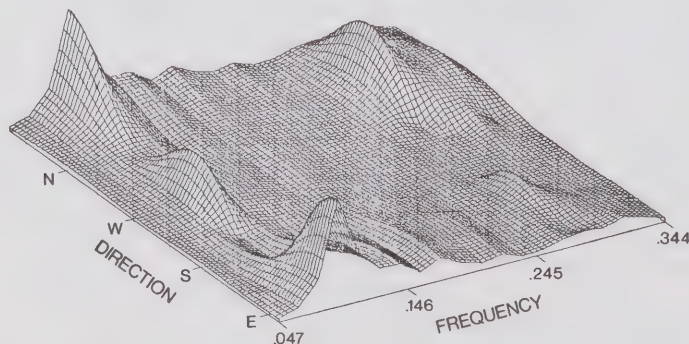


Figure 6. A perspective plot of the directional spectrum of a wave record from the motion package buoy. The low frequency waves appear to be swell from the ENE. The high frequency waves are sea from the north responding to a rising north wind (plot courtesy of R.B. Long, NOAA).

data were prepared in two formats, one suitable for archiving at the National Ocean Data Center, NOAA, Washington, and one for input into the directional spectral model developed by Dr. R. Long of the Air Sea Interaction Laboratory, NOAA, Miami. Dr. Long's group is cooperating with us in applying his statistical model to our data and in examining the response of the waves to varying wind conditions. An example of the perspective plot of a directional spectrum is shown in Figure 6.

### **Geotechnical Study of Eroding Bluffs**

The study site is located approximately 3 km east of Port Burwell on the Lake Erie north shore. The purpose of the study is to document and analyse principal shore variables, as opposed to lake variables such as waves and lake levels, in the process of bluff recession.

Long-term monitoring of pore pressures is approaching its completion because by now the installation of piezometers and conducting cables is very close to the edge of the bluff. Significant results were obtained in early November 1981 when the record from two piezometers indicated a rapid decrease of pore pressures associated with slumping. Successful monitoring of such short-time events in the literature is extremely rare.

In 1981 changes in shore morphology at the study site were documented by a new topographic survey. The results of five previous surveys were evaluated in an unpublished report. Slope stability analyses using measured slope profiles and pores pressures in combination with laboratory geotechnical data are underway.

Monitoring of two slope indicator casings until their destruction by slumps did not detect any significant deep-seated subsurface displacements. The results indicate that progressive failures, found to be of importance elsewhere in stability problems, do not occur at Port Burwell.

### **Laboratory Test of Sediment Erodibility**

Knowledge of sediment erodibility under controlled hydraulic conditions is important for a better understanding of shore and sub-aqueous erosion. A study was therefore initiated to develop a testing method which would permit the measurement of erosion of cohesive sediments when they are subjected to predetermined shear stresses. During the fiscal year, the first prototype of a rotating-cylinder apparatus for testing of natural and compacted specimens has been developed. The apparatus has been calibrated to obtain rpm-torque relationships for three different values of hydrodynamic roughness. Initial tests have been carried out with 10-cm diameter specimens of clayey till. With few exceptions, consistent amounts of eroded material were measured for controlled values of the shear stress. It is expected that the study will continue for the next two fiscal years during which time the apparatus will be further modified and improved. Compilation



of annotated abstracts of literature concerned with erosion of cohesive sediments has been undertaken in connection with this study.

### **Nearshore Sediment Program**

Nearshore sediments data have been converted from a punch-card base to computer disk and tape files and the operations for data reduction and retrieval have been streamlined with the use of a computer terminal and the editor, X-EDIT. Half the data have been revised and compiled as listings and plots in a form suitable for publication.

Seven data reports were compiled to answer internal and external requests for Lakes Ontario and Erie nearshore data.

### **Nearshore Profile Change**

Fixed-transducer studies of nearshore profile change were carried out at the Van Wagner's Beach site, Hamilton from May to January 1982. Levelling of the exposed beach was incorporated into the survey to extend the measured profile from the waterline to the back-beach area. Measurements of profile change during storms were made with an automatic datalogger installed on the lakeward slope of the second bar. Data from 1981 indicate that, in general, only the portion of the profile inshore of the 3-m contour responds to storm waves, and that wave energy is inadequate to keep the profile in adjustment with changing lake level.

### **Floating Tire Breakwater Research**

Two-dimensional hydraulic model tests of pipe-tire floating breakwaters were completed. A data report and a report on the wave transmission and mooring force characteristics of pipe-tire breakwaters have been finished.

A series of tests was conducted in the NWRI towing tank to measure the drag force on pipe-tire breakwater models. The results are documented in a report which enables the estimation of breakwater mooring forces induced by currents as well as the towing force required to move a breakwater.

The construction and installation of a Goodyear-type floating tire breakwater in Burlington, Ontario was observed and documented in a film and in a report. The breakwater contains 35,000 car tires and is believed to be the world's largest floating tire breakwater. A field study to measure wave transmission and mooring force characteristics of one discrete breakwater section, 128 m long by 18 m wide, was initiated at this site. Electronic problems were encountered with the monitoring equipment and consequently very little useful data were collected. The equipment is being modified for the 1982 field season.

Some flotation tests on prototype scale car and truck tires were conducted in the Hydraulics Laboratory. A report on floating tire breakwater buoyancy requirements is in preparation. For continued flotation of a floating tire breakwater, it is now recognized that some form of supplemental flotation must be provided. The report enables the estimation of supplemental flotation requirements for a Wave-Maze, a Goodyear FTB and a Pipe-Tire breakwater.

### **Comparison of Manual Wave Prediction Models**

A comparison of three manual wave prediction models has been carried out using 1972 waverider data from two deep water locations in Lake Ontario. The commonly used Sverdrup-Munk-Bretschneider model was compared with the JONSWAP model and with the new model of NWRI's Donelan. The latter model is the first simple model capable of predicting the dominant wave direction; other simple models assume coincident wind and wave directions. Only fetch-limited, pseudo steady-state events have been investigated. The accuracies in predicting the characteristic wave height and the period of the peak of the wave energy spectrum were found to be comparable for all three models with standard errors of about 0.25 m and 0.6 s respectively. However, the accuracy of the Donelan model was found to be slightly superior to that of the other two models and, because the Donelan model also predicts the direction of the peak energy waves, it could prove useful for engineering applications in steady fetch-limited conditions over deep water. A report has been completed.

### **Verification of Waverider Data**

The finite difference numerical model of NWRI's Donelan was used to verify 1972 waverider data collected by the Marine Environmental Data Service at three locations in Lake Ontario. The measurements at Toronto and at Main Duck Island were verified as good data but the Cobourg measurements were found to contain numerous timing problems. These problems are being corrected by MEDS (Marine Environmental Data Service, Fisheries and Oceans Canada). Results of this investigation are summarized in a Technical Note.

### **Tarsiut Island Overtopping Study**

The wind-wave flume in the Hydraulics Laboratory was rented to W. F. Baird & Associates Coastal Engineers Limited for several weeks to study overtopping of, and associated remedial measures for, Tarsiut Island. This is a caisson-retained artificial island used for oil exploration in the Beaufort Sea involving both Gulf Resources and Dome Petroleum. Overtopping by green water and spray was modelled and filmed with a high speed movie camera. Assistance for this study was provided by Hydraulics Division professional staff and technicians. The study results remain the property of the client.

## Port Burwell Shoreline Recession Study

The sand budget for the Lake Erie shore from Port Glasgow to Long Point has been estimated using bluff erosion rate data, bluff stratigraphic data, nearshore survey data and information from other existing reports. The importance of the sand size to be considered in alongshore transport rates is discussed. Results are presented in a Technical Note for limited distribution.

## The Dependence of the Aerodynamic Drag Coefficient on Wave Parameters

The conventional, but dimensionally inconsistent, practice of relating the drag coefficient to the wind speed is generally justified on the grounds that the roughness elements are the short waves which are in close equilibrium with the local wind. A large quantity of Reynolds stress measurements over a wide range of fetches is used to demonstrate that the waves near the spectral peak can contribute substantially to the total stress. At very short non-dimensional fetches, these waves are the primary roughness elements. A model is proposed for the roughness of the surface including the mobility (phase speed) of the various roughness elements. For simplicity, the model treats the wave spectrum in two parts: (1) the rear face or equilibrium range which is assumed to be travelling in the wind direction; and (2) the spectral peak which, having been generated elsewhere, may be at an angle to the local wind. When the model is compared with observations (Figure 7) the agreement is almost within the sampling variability of the observations.

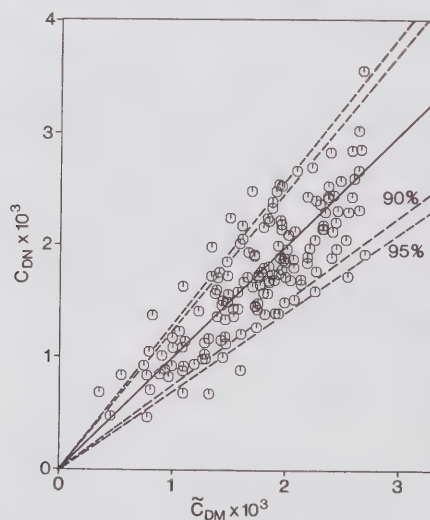


Figure 7. Observed neutral drag coefficient estimates  $C_{DN}$  compared with the modeled values  $\tilde{C}_{DM}$ . The line of perfect agreement is shown (solid) as are the 90% and 95% confidence limits (dashed) based on the sampling variability of  $C_{DN}$ .



## An Extended Miles' Theory for Wave Generation by Wind

Miles' inviscid theory of surface wave generation by wind is (a) modified by replacing the logarithmic shear velocity profile with one which applies right down to the wave surface and which exhibits an explicit dependence on the roughness of the surface, and (b) extended to include the effects of the interaction of wave with air flow turbulence by considering the wave-modified mean flow as the mean of the actual turbulent air flow over water waves and using this in a mixing-length model.

The surface pressure is shown to depend significantly on the flow conditions being aerodynamically smooth or rough. Its component in phase with the surface elevation is practically unaffected by the wave-turbulence interaction. However, such interaction tends to increase the rate of energy input  $\beta$  from wind to waves travelling in the same direction, e.g., the increase in  $2\kappa^2$  for aerodynamically rough flow, where  $\kappa$  is the von Karman constant. It also provides damping of waves in an adverse wind which can be about 10% of the growth rate in a favourable wind.

## TECHNICAL SERVICES SECTION

The major functions of the Section are:

- Provision of technical support to assist scientists and engineers of the Environmental Hydraulics and Shore Processes Sections with their research studies.
- Calibration and performance evaluation tests on water current meters and other hydrometric equipment using the towing tank.
- Performance testing of equipment exposed to cold weather using the environmental testing chambers.
- Determining friction coefficient factors in venturis and pipes using the pipe calibration facility.
- Performing sedimentological and geotechnical tests and analysis in the sedimentology and geotechnical laboratories, the core testing laboratory and x-ray room.
- Provision of skilled trade services such as carpentry, mechanics, photography and electronics to users of the Hydraulics Laboratories and the maintenance of major equipment and instrumentation.

The Section is divided into four units which interact to perform these services.

### **Environmental Hydraulics Support Unit**

Staff of this scientific support Unit are assigned to research studies under the guidance of scientists or engineers of the Environmental Hydraulics Section. Involvement in the studies consists of the setting up of experiments in the laboratory and at field sites, collecting, evaluating and analysing data and the writing of technical reports.

### **Shore Processes Support Unit**

Technical staff of the Unit are assigned to research studies under guidance of scientists of the Shore Processes Section. The Unit operates geotechnical, sedimentological and x-ray laboratories where grain-size and geotechnical analyses of sediment samples and cores are undertaken. These facilities provide support for ongoing research within the Division as well as outside agencies.

### **Laboratory Services**

Support to users of the laboratories was provided in areas such as woodworking, machining, electronics, photography and inventory control.

**TECHNICAL OPERATIONS DIVISION**





The mandate of the Technical Operations Division is to provide technical leadership, field expertise, and technical support to the field research operations of NWRI, its regions and, where possible, to other departments, agencies and universities.

Areas of responsibility include field measurement, sample collection, and some basic analyses of physical, chemical, biological parameters, and sediments from freshwater systems aboard major research ships, launches and shore-based field parties. This Division is also responsible for the preparation, modification, field use, and maintenance of a wide variety of mechanical, electronic and hydraulic sampling and data acquisition systems, and diving operations.

This role also includes responsibility for acquisition, maintenance and scheduling of the NWRI vehicle fleet, laboratory trailers, and for field equipment issue. Technical Operations riggers provide the essential shop, highbay, forklift, heavy truck and rigging support to ships operations and field parties.

### CSS LIMNOS

#### Lake Ontario

During the 1981/82 field season, Technical Operations supported 34 cruises on Lake Ontario utilizing the CSS LIMNOS which is operated by Ocean Science & Surveys, Bayfield Laboratory for Marine Science & Surveys, Department of Fisheries & Oceans. Briefly, the major cruises consisted of:

- 11 Open Lake Surveillance
- 8 Sediment Trap Moorings
- 8 Chemical Forms and Availability of Trace Metals
- 3 Long Term Biological Index Monitoring  
(CSS BAYFIELD completed this work)
- 1 Metabolism Study
- 1 Net Flux and Sedimentation of Phosphorus and Carbon
- 1 Time Series Trap Experiment and Sediment Resuspension
- 1 Sediment Bank Study

### Surveillance

In 1974, the Open Lakes Surveillance Program was initiated to study the effectiveness of the water management programs, to assess water quality and to gain further knowledge of limnological processes. The data generated from this program have served as input to the Great Lakes Water Quality Board Annual Report to the International Joint Commission.

In the 1981 field season, 94 stations were occupied on Lake Ontario during each of the 11 scheduled cruises. The basic surveillance parameters observed were: temperature profile, dissolved oxygen, specific conductance, pH, chlorophyll a, phytoplankton, particulate

organic carbon, total phosphorus unfiltered, chloride, percent transmission, Secchi disc during daylight hours and meteorological observations. To facilitate these tasks, the ship was equipped with electronic bathythermographs (EBT), rosette/electronic bathythermograph system, transmissometer/electronic bathythermograph system, winches for chemical and biological water sampling and radar as well as Loran-C positioning systems.

In addition to the basic surveillance program, 4 chemistry cruises and 4 microbiology cruises were 'piggy-backed' onto the cruises. Various other projects were fitted in the schedule, including: a Met. mooring installed at Glenora in support of the Great Lakes Fisheries Research Branch, PFF; sediment samples for Hydraulics Division and Aquatic Physics & Systems Division and water samples for Radiochemistry Section, Environmental Contaminants Division of NWRI and the University of Waterloo.

### Sediment Trap Moorings

Eight cruises were conducted in Western Lake Ontario in support of this study by Aquatic Ecology Division, NWRI. The purpose of these cruises was: 1) to measure the sedimentation and the regeneration rates of nutrients and contaminants; and, 2) to determine the fate of material loaded by the Niagara River as an aspect of inshore-offshore water quality differences.

At 6 locations, sediment traps were positioned and then refurbished monthly. On selected cruises, an EBT/transmissometer survey of the Niagara River plume was done and a newly-designed dissolved oxygen profiling system was utilized at each sediment trap mooring site.

### Chemical Forms and Availability of Trace Metals

A series of eight cruises was supported to study particle dynamics and their role in regulating trace element forms and availability. This Environmental Contaminants Division study is to provide input into the Canada/U.S. Great Lakes Water Quality Agreement.

During each of the cruises, 4 stations were visited in Western Lake Ontario. Data collection involved the centrifuging of large volume water samples, sampling from discrete depths for water chemistry and the generation of transmission and temperature profiles. On designated cruises, sediment samples were also obtained.

### Metabolism Study

This project consisted of a single cruise for Aquatic Ecology Division to determine the relationship between nutrient uptake and primary and secondary production. The vessel was moored for a 3½ day period at a single station in the Central Basin where primary productivity experiments were conducted, zooplankton grazing chambers were



deployed and frequent water samples were taken for chemical and biological analyses.

### Net Flux and Sedimentation of Phosphorus and Carbon

Sedimentation traps and settling chambers were used to determine the 24-hour settling flux, with an emphasis given to particulate phosphorus and particulate organic carbon. Also studied was the net downward flux of particulates and associated PCB's for different size ranges.

Each of the 4 stations distributed throughout the lake was occupied for a 24-hour period. During this time, a sediment trap mooring and particulate organic carbon settling chambers were deployed and retrieved at predetermined times. Temperature and transmission profiles, plus samples for water quality and nutrient analyses, were obtained.

### Time Series Trap Experiment and Sediment Resuspension

The objectives of this one cruise were 1) to measure phosphorus and carbon sedimentation from one to five days' exposure using sedimentation traps; and, 2) to attempt the measurement of bottom resuspension as a function of current speed.

Five sedimentation trap moorings were deployed in the work area in Western Lake Ontario. On each consecutive day thereafter, one of the moorings was removed. A resuspension tripod mooring was also deployed and retrieved daily.

### Sediment Bank Study

In order to expand the Great Lakes Sediment Bank, large volumes of sediments were collected from 46 stations located in the Western, Central, Eastern, and Kingston basins. These samples will permit retroactive analyses of persistent toxic substances which are relevant to the Canada/U.S. Great Lakes Water Quality Agreement of 1978.

### Lake Erie

#### Internal Loading of Nutrient Oxygen Depletion Cruise

This was the only cruise of this nature conducted during the 1981 field season. The pore-water chemistry in the Central Basin was examined to provide input to the Lake Erie oxygen demand and eutrophication process. Water chemistry and sediment samples were collected from 21 stations throughout the Eastern and Central basins.

## CSS BAYFIELD

### Great Lakes Algal Physiology and Ecology Cruises

Great Lakes Fisheries Research Branch, with the support of Technical Operations Division, undertook studies to investigate the relationship of light, temperature and nutrients to phytoplankton productivity. The effects of various toxic metals on algal metabolism were also examined using shipboard incubators. The project consisted of three 2-week cruises aboard the CSS BAYFIELD. During each cruise, 25 stations located in Lakes Ontario, St. Clair, Erie, Huron, and Superior, Georgian Bay and the North Channel were occupied.

### Long Term Biological Index Monitoring

Since temporal variability is of much greater significance than spatial variability for most areas of concern, it is important to establish more precisely the seasonal trends of those parameters. GLFRB initiated a prolonged study in 1981 to investigate this situation with the objective of determining an optimum sampling strategy over the next few years. This program involved a time intensive series of chemical and biological sampling from Lake Ontario on a weekly basis. To accommodate this schedule, the CSS LIMNOS, BAYFIELD and ADVENT were utilized at some point during the program with the bulk of the work being handled by the BAYFIELD.

A major part of the program was the weekly refurbishment of sediment trap moorings located near 4 of the 6 water-sampling stations. Ponar grabs were also taken to determine the population abundance of benthic fauna and the growth rates of the dominant genus (Pontoporeia).

### GLFRB Georgian Bay Benthic Survey

The effects of airborne contaminants probably extend beyond the small inland lakes to some of the small bays emptying into Georgian Bay. In order to obtain baseline data on the natural communities in these areas and to estimate the current contaminant levels, a coastal survey was conducted from Little Current to the Moon River during August and September of 1981. Many different aspects of small bay ecology were studied and samples were taken of the water, benthic fauna, zooplankton, macrophytes, and invertebrate and fish populations. The CSS ADVENT was the principal research vessel and two smaller launches were also operated. Divers were frequently used to sample and observe the littoral zone.

### Acid Rain

Due to the increasing concern over the effects of airborne contaminants on small lakes, the Federal Government has initiated an intensive study in the Algoma District on the east shore of Lake Superior. Since 1978, the primary study site has been the Turkey Lakes

Forested Watershed which is a series of 5 major lakes located approximately 80 km north of Sault Ste. Marie. This project will involve several government agencies in a concentrated effort over the next few years.

Technical Operations Division provided field and logistical support to the 2 major programs conducted by GLFRB and NWRI. The field work consisted of an extensive sampling program and consolidating the site for future work.

### Canadian Wildlife Service

The surveillance of toxic substances in Great Lakes wildlife by the Canadian Wildlife Service was continued in the spring of 1981 with the support of Technical Operations Division. CWS has been regularly monitoring the effects of toxic substances on the Herring Gull in the 4 Canadian Great Lakes since 1975. These effects are reflected in egg loading and birds' reproductive success rate. The steadily decreasing reproductive success rate over the past 4 years of the IJC monitor colony located on Agawa Rocks determined the focus of this year's studies to the eastern shore of Lake Superior. The objectives of the 1981 survey were: 1) to determine the extent of the reproductive problems; and 2) to attempt to identify the source of the problems.

Intensive breeding assessments and a census of all the colonial fish-eating birds along the 136 km coastline study area were accomplished. Reproductive assessments were made of selected gull colonies in Georgian Bay and Lake Superior. In addition, all the known Double Crescended Cormorant colonies in the Canadian Great Lakes were visited and most of the young received leg bands.

One full-time Technical Operations staff member was supplied to CWS along with a vehicle. Two 17-foot launches supplied by OSS were utilized during the field season and their combined boating distance was close to 3200 km.

### Port Burwell Erosion Studies

As part of a program initiated in 1975, Hydraulics Division continued its comprehensive study to understand the factors involved in bluff erosion and failure. Technical Operations staff surveyed and compiled a topographic map of the study area near Port Burwell on the North side of Lake Erie. Several 1 cubic foot block samples were also collected to measure the erodibility of cohesive soils.

### Sediment Drift Studies

In 1976, Van Wagner's Beach, Hamilton was chosen as a site for experimental measurements of littoral drift because of accessibility, existing meteorological data collection systems and the Beach Stability Program conducted there in 1972/73.



In support of Hydraulics Division, Technical Operations staff conducted echo-sounding surveys along 3 lines at predetermined time intervals throughout the ice-free period of the year. Along one of the lines, Profile 18, steel T-stake frames were jetted into the sediment. Transducers mounted on these frames were used to monitor the depth of the sediment water-interface.

### **Solids and Surf Zone Currents**

The purpose of this Hydraulics Division Project was to predict sediment drift and surf zone currents in the nearshore areas at study sites at Van Wagner's Beach and 50-Mile Point. Littoral currents were examined using a drogue launched with a skeet launcher and then fixing its position at rapid intervals with two survey theodolites.

The SOLIDS Survey, conducted at Van Wagner's Beach only, involved 17 sounding lines with sediment samples taken at 1 m bottom contour intervals. A Distomat, an electronic infra-red measuring device, was utilized by the staff as a positioning system.

### **Other Projects**

Numerous other projects were supported by Technical Operations Division during the 1981 field season. These included: centrifuging and coring at two lakes in Algonquin park for Aquatic Ecology Division; sediment coring at Port Granby, Ontario for Environmental Contaminants Division; and the study of organic compounds in Canagagigue Creek near Elmira, Ontario for ECD and the Grand River Conservation Authority.

### **Underwater Operations Unit**

The Unit is responsible for all diving operations conducted at CCIW and within NWRI. In 1981 there were 22 divers certified and equipped by the Unit. A new DOE Departmental Directive for Diving Safety was prepared by Personnel Directorate with input from NWRI and issued to all CCIW divers.

Scheduled dive support was given to several projects. The Unit supported Lake Trout Habitat Studies (Director's Office), utilizing underwater television, side-scan sonar and still photography. Divers were used extensively in the Sediment Drift Studies off Van Wagner's Beach to install and maintain instrumentation. The unit was also involved in the deployment and retrieval of VAPS, CATTs and M-CATS (measuring systems), and in the installation of instrumentation on the Floating Tire Breakwater at LaSalle Park, Burlington. The Unit also supported OSS, BLMSS, DFO; GLBL, PFF and NWRI on a contingency basis several times throughout the year.

## Limnological Instrumentation Section

The establishment of an Instrumentation Section within the Division has increased the Division's expertise in this field and immediate response for support in instrumentation has been possible. As a further improvement in operating procedure, it was decided to annex the field instruments and data sub groups within the Section. The Instrumentation Section is now divided into two units: 1) Current Meters and Data Abstraction Unit; and, 2) Field Instruments and Meteorological Systems Unit.

Work is progressing on two portable EBT units for field use. Two processor-controlled monitor packages were designed and built for Plessey/Hymet/9031/Aanderaa current meters. Units are being field tested at present and it is hoped to replace all the old Plessey monitors by Fall, 1982.

Support in the form of logistics, instrument maintenance and quality control was provided throughout 1981 for NWRI ship systems, electronic and ancillary electronic equipment.

Five meteorological sites were operated throughout 1981. A total of 20 tapes of data were edited for the period ending October 1981. All 1980 met. data is being re-edited. The meteorological and temperature data are archived by CCIW's Data Management Archiving Unit and are used by the scientific community, for the most part, as support data for large projects such as the Acid Rain Study (Sault Ste. Marie) and Water Management Research.

## Rigging Unit

The rigging staff, shop and highbay facilities provide direct and indirect support to the field activities of NWRI divisions as well as the other agencies within CCIW.

Dockside support to ships, mooring arrays and equipment preparation for field parties, maintenance of mechanical sampling equipment, forklift, heavy truck driving, NWRI vehicle fleet maintenance, and field stores is provided. This year, sample and equipment transport ranged from Saskatoon to Halifax. The Unit also provided some trailer-towing services.





**STAFF SERVICES DIVISION**



Staff Services Division (SSD) is the lead agency for the provision of administration, financial, materiel management, records management and property management to all Environmental Conservation Service elements, as well as to those of the Environmental Protection Service, located at the Canada Centre for Inland Waters. In addition, common services are provided to Fisheries and Oceans which includes Bayfield Laboratory for Marine Science and Surveys, Great Lakes Fisheries Research Branch and Canadian Hydrographic Service, Department of Supply and Services and Personnel Administration (Ontario Region). Expertise is also provided to supporting committees such as facilities, safety, security, fire prevention and energy conservation.

### **Building and Property Services Section**

This Section is responsible for the physical operation and maintenance of the buildings, intrinsic equipment and the grounds, roadways and parking lots within the confines of the complex. It also provides technical assistance and advice concerning alterations, modifications or equipment installation for all CCIW facilities to satisfy in-house occupant requirements.

A total of 89 service contracts were processed including:

- a) greenhouse installation for Aquatic Ecology Division;
- b) construction of "Oceans" workshop in the W/W covered storage area;
- c) asbestos removal project in the Wastewater Treatment Centre;
- d) upgrading the main laboratory buildings' waste system by eliminating the majority of gang trapping;
- e) replacing a large portion of the mall quarry tile floor; and
- f) renovating the cafeteria kitchen and server area, including the replacement of faulty quarry tile floor.

BPS issued 496 work authorities to contractors. These included the replacement of the entire Mercury Vapour Lighting System in the Hydraulics Laboratory with Metal Halide, placing the basic heating system on emergency power, and extensive repairs to all main complex roofs. In addition, 681 maintenance orders, and 33 other work orders were issued to contractors.

### **Telecommunications Section**

Building and Property Services is responsible for the 55 line PBX servicing over 600 telephones, data and other communications systems throughout the complex. A total of 71 changes were made to various lines/equipment and the major change was the introduction of the Call Detail Recording System. This system records telephone calls made on Centrex/WATS lines in much the same manner as Bell Canada records Direct Distance Dialling.



A problem with cross conversations on some lines was turned over to Bell Canada Engineering. After much searching, a faulty trunk line from Hamilton was discovered and the fault corrected.

### **Safety, Fire and Security Section**

Safety committees of each division/directorate met on a regular basis. Four St. John Ambulance first aid courses were held, graduating 34 students. Regular safety inspections and investigations were conducted. Individual safety committees are very conscientious and follow-up on all items is very effective.

Fire safety equipment has been completely inspected and serviced. Two fire drills were held and the organization worked well. Training on all on-site fire fighting equipment was conducted for the various groups throughout the Centre.

Security patrols are carried out on a regular basis. Approximately 21,000 visitors came into the complex through the year. The government identification card program has been maintained for full-time continuing staff.

### **Information Unit**

The Unit provides the answers to queries received from academics and scientists as well as general public. In addition, officials from municipal, provincial and federal agencies also request information. Over the period covered by this report some 1800 enquiries, verbal and written, and ranging from requests for scientific data and reports, the levels of the water in the Great Lakes, where and how to apply for fishing and gun licences, and last but not least, how to apply for the old age pension were processed.

A brochure, describing in general terms the work of the Divisions was published. Assistance was given in producing a combined DOE/DFO slide show describing the components and their work located within the CCIW complex. Extensive use was made of this show during Open House '82 and it is currently being shown to visitors to the Centre. It is also available to outside groups such as church organizations, service clubs and schools when accompanied by a Centre representative.

Open House '82 required considerable preparation time in order to acquaint the area educators with the program and to schedule their arrival to avoid unnecessary congestion and delay. During registration, a copy of the Canada Water Year Book 1979-80 was made available to the leaders of each group of students. Open House '82 accommodated in excess of 20,000 visitors during the four-day period.

Requests for speakers on specific subjects by service clubs, professional groups, universities and colleges are accommodated on an individual basis. A comprehensive knowledge of the staff complement is required to provide the most suitable representative for the subject to be discussed.

### Library Activities Section

CCIW library services and facilities are provided to support the research and survey programs carried out at CCIW.

During the 1980-81 fiscal year, changes occurred in all library positions. Hence, some library services had to be suspended in order that essential services could be maintained at a high standard. Staffing difficulties extended beyond the fiscal year. However, it was possible, through the use of temporary staff, to complete the following projects: four bibliographies of CCIW and NWRI authored publications for the years 1979 and 1980, the establishment of a circulation file by requestor, the completion of a survey of all the library's exchange institutes, update of library exchange files, reorganization of library files in Central Registry, storage of accounting files for the years 1972-80, establishment of basic statistics for library operations, and the preparation for binding of a total of 172 journals.

### Materiel Management Section

The 1980-81 fiscal year has been one of adjustments necessitate perpetuated by staff changes, retirement and streamlining of positions in an effort to continue a high level of service.

A centralized filing system for Financial Services and Materiel Management is now in place, although some modification is required to eliminate functional problems. Additional modifications in supply and shipping/receiving have eliminated considerable paper work, without jeopardizing required statistics or other information. The control and handling of laboratory waste is greatly improved, with the holding area isolated and secure outside the building.

The volume of work has increased at every desk and work station and we are viewing new undertakings in the future. Additional job training outside, as well as cross-training staff occupying related positions is a priority.

The NWRI computerized inventory control system received a great deal of interest and compliments throughout the Department. We intend to show that as yet it has only been seen as a record keeping tool when, in fact, the record keeping is only the gathering of base information that will allow Materiel Management to advance in other areas, i.e. Full Cycle Assets Management, maintenance factors, repair or trade decisions. An additional aspect of the assets management is the control of definite consumables.

### Financial Section

The Financial Section (NWRI) provides centralized computer accounting services for all ECS units located at CCIW. (NWRI, Inland Waters Directorate (Ont), and Lands Directorate (Ont.)). It also

provides the accounting function for funds provided by the Regional Director General (Ont. Region) for the Great Lakes Water Quality Agreement.

It also provides liaison between other government departments (federal, provincial and municipal) and suppliers in relationship to payments of accounts and contracts.

In addition, the Section is responsible for handling in excess of 1300 cheques annually (salary and travel expenses) and processes an estimated 20,000- 25,000 invoices and various types of claims annually.

### **Central Registry**

Central Registry provides mail services to all in-house occupants as well as registry facilities for NWRI and Inland Waters Directorate. Telex, telecopier and photocopying services are provided for the Centre. In order to reduce the cost of photocopying, a study was carried out to review the cost efficiency of the photocopying equipment at CCIW.



## REGIONAL REPORTS



## WESTERN AND NORTHERN REGION

The National Water Research Institute, Western and Northern Region (W&N) is located on the University of Manitoba campus in the Freshwater Institute Building, 501 University Crescent, Winnipeg. The Western and Northern Region of the Inland Waters Directorate consists of the prairie provinces and the Northwest Territories. Much of the prairie region is semi-arid but susceptible to severe spring floods. Lakes are generally shallow and tend to be saline. These and other facets of the prairie region often make environmental problems unique to this region. The Western and Northern Region Branch fulfills the need for local expertise in problem areas specifically regional in nature. The usual complement of this regional Branch of NWRI is four scientists and five technicians but in 1981 the Branch was understaffed due to recent resignations (three scientists and four technical personnel).

NWRI conducts applied research related to water management problems throughout the prairie provinces and the Northwest Territories. Federal legislation such as the Arctic Water Pollution Prevention Act, the Boundary Waters Act, the Canada Water Act, the Department of the Environment Act and the Environmental Contaminants Act provides the mandate for much of the research in this region. Attention in 1981 focused on:

- i) the effects on aquatic ecosystems of toxic contaminants such as mercury or other heavy metals introduced to the waters from municipal, agricultural, or industrial sources;
- ii) the eutrophication, or cultural enrichment of shallow prairie lakes by municipal and agricultural effluents containing an overabundance of the plant nutrients, phosphorus and nitrogen.

## Mercury Pollution in the Wabigoon River System

The project on mercury biogeochemistry in the Wabigoon River-English River system (Northwestern Ontario) was completed, and results have been published or are in press. This research was initiated in 1978 and was subsequently amalgamated with a larger project supported jointly by the governments of Canada and Ontario under the terms of the Canada Water Act. The study emphasized mercury speciation, availability, and partitioning between water, suspended particulates, bottom sediments, and biota as related to geographically and seasonally varying environmental conditions. The results indicate that methyl mercury levels depend more on environmental variables such as temperature, pH, nutrient supply, microbial activity, and the abundance and nature of mercury-binding sediment components such as iron and manganese oxides, sulfides, humic matter, and exchange sites on clay than on total mercury levels. With increasing distance downstream from the source of pollution (a chlor-alkali plant at Dryden, Ontario), total mercury levels in sediments decrease sharply, but the mercury becomes more



available and more readily methylated (Figure 1A), paralleling a gradual change in sediment composition from wood fragments to clay-silt mud. Thus, methyl mercury concentrations in sediments remain high despite the drop in total mercury. Similarly, in unpolluted sediments, total mercury levels are low but the relative availability is high, as shown by data for methyl and DTPA-extractable mercury (Figure 1B). In the river, total and methyl mercury are mostly particulate during the spring flood owing to sediment resuspension, but in the summer, dissolved forms predominate owing to microbial methylating activity and desorption of sedimentary mercury by salts (Figures 2A, B and C). Mercury is more readily desorbed from clay-silt mud relatively far from Dryden than from the wood-chip deposits closer to the source (and thus is probably more available). Dissolved mercury species are probably more bio-available than particulate forms (which are 98 to 100% insoluble in mild extractants such as calcium chloride, dilute acetic acid, and DTPA solutions) though the solubility increases in the summer (Figure 2D). In general, the mercury is probably most available to organisms in the summer. Pelagic fish in lakes fed by the Wabigoon River are continually contaminated by riverborne methyl mercury introduced into the epilimnetic waters, while mercury in the sediments of these lakes have the greatest effect on bottom feeding animals. The results of the study have implications for any management decisions related to remedial action.

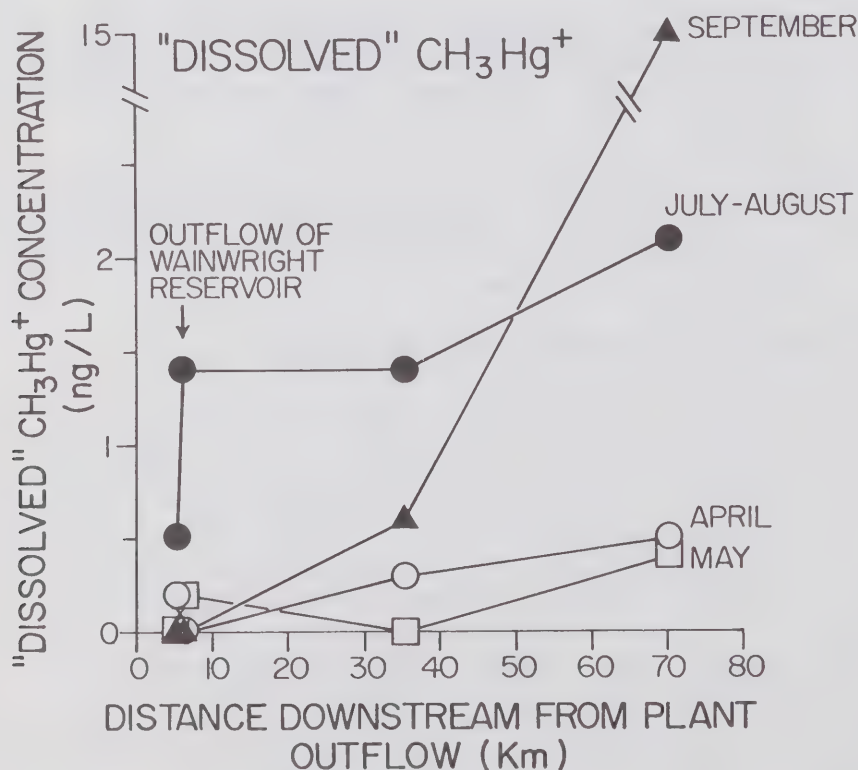


Figure 1a. "Dissolved"  $\text{CH}_3\text{Hg}^+$  Concentration - Distance downstream from plant outflow.

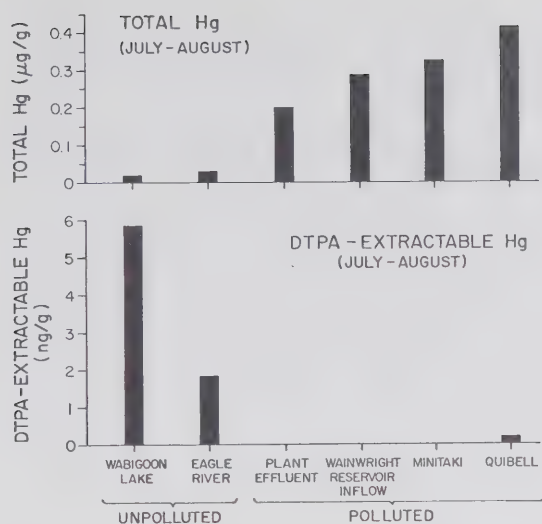


Figure 1b. DTPA-EXTRACTABLE Hg - Total Hg ( $\mu\text{g/g}$ ).

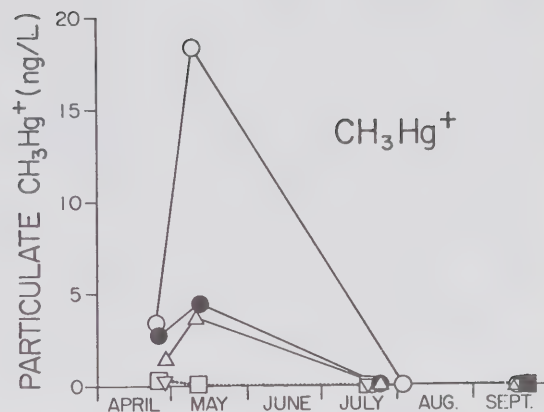


Figure 2a. Particulate  $\text{CH}_3\text{Hg}^+$  ( $\text{ng/L}$ )

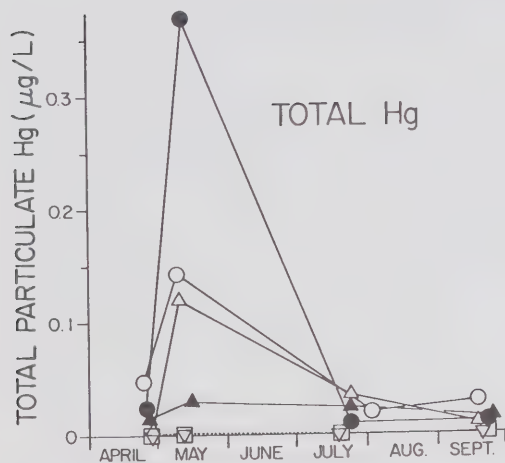


Figure 2b. Total Particulate Hg ( $\mu\text{g/L}$ )

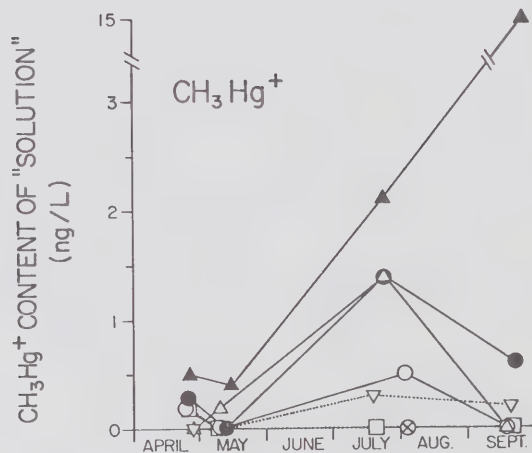


Figure 2c.  $\text{CH}_3\text{Hg}^+$  Content of "Solution" ( $\text{ng/L}$ )

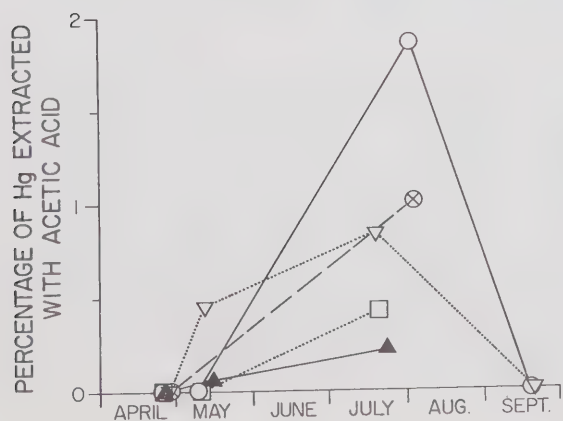


Figure 2d. Percentage of Hg extracted with acetic acid.

## Mercury Research

In 1981 research projects on the biogeochemistry of mercury (again, with emphasis on speciation, availability, and partitioning) were initiated in the Qu'Appelle River-Fishing Lakes system and Moose Jaw River (Saskatchewan) and in lakes and reservoirs (including Southern Indian Lake) in Northern Manitoba. Two experimental laboratory projects involving methyl mercury uptake by fish fry, and mercury methylation and demethylation by sedimentary micro-organisms under controlled conditions were also undertaken. In addition, heavy metals in various sample materials from lakes and rivers are being analyzed by electron microprobe under contract to Dr. T. Bistricki of Metafuse Ltd. All of these projects are continuing at the present time. Research done in late 1981 and early 1982 was assisted by funding from the Toxic Contaminants Management Program.

## Nutrient Loading Models

Shallow prairie lakes are naturally rich and highly productive. Summer algal blooms inhibit recreational and other uses of the few available lakes near large population centres. Reduction of nutrients from municipal sources is thought to improve the situation -- but how much nutrient reduction is required for significant improvement? Data on nutrient-productivity relationships in the prairies are not available. In other regions nutrient loading models have been used to predict future trophic levels to be expected following the construction of tertiary sewage treatment plants. The simplest of these models is available in nomograph form which facilitates application to real lakes. However, available nutrient loading models are based largely on data from temperate lakes outside the prairie region. A study was conducted to evaluate available nutrient loading models and, in particular, the potential applicability of nutrient loading models to the prairie region. The results (Kenney, 1980; Kenney, 1981) are an indictment of many of the available models. Several of the nutrient loading models examined were found to be mathematically unsound. Another was based upon an unwarranted assumption about the state of phosphorus equilibrium in lakes. The successful application of the model approach to simulate nutrient dynamics in prairie lakes appears feasible but not with the available models or the existing data base.

## The Qu'Appelle Lakes Study

Undertaken as a baseline study to establish current levels of trophic in the lakes (so that the effectiveness of restoration measures being instituted throughout the basin could be gauged in subsequent years), the study was expanded when it was found that a high proportion of the chironomid larvae in the lakes were deformed, presumably by environmental contaminants. The effects of contaminants appear to have been particularly severe in Pasqua Lake, the first lake in the system to receive inputs from major upstream sources. In the deepest basin of this lake, the only remaining fauna in what should normally be a very



productive body of water is a remnant chironomid fauna. The natural gradient formed by the six downstream lakes presents an opportunity to examine the response of chironomid communities to varying levels of contaminant inputs, degradation processes and basin variability.

### Palaeolimnology of Pasqua Lake

Originally conceived to determine the evolution of eutrophication in Pasqua Lake, the study is proving useful by providing background data on the rates of deformities to be expected in pre-chemical age chironomid communities. This information, unfortunately, is restricted to those types of deformities confined to preserved hard parts of the larval head shield and do not include those occurring in the more fragile structures which are easily lost by sediment abrasion. The analysis of chironomid remains in sediment cores collected in March 1979, indicate that Pasqua Lake was eutrophic (TIN 13) to strongly eutrophic (TIN 14) prior to the cultural development in the province. Some evidence in the more recent sediments of the core suggest that productivity in the lake has been increased by cultural development, but the chironomid fauna has been so badly decimated by contaminants that it is difficult to gauge accurately the changes in productivity. At this point it is unclear whether the loadings of contaminants to the lakes are substantial, or whether their effects are magnified by the severe conditions existing in the lake, particularly under ice cover.

### Tobin Reservoir Contamination Study

A multi-disciplinary, interagency project involving chemists, bioassayists and biologists from EPS, University of Manitoba, and NWRI-WNR, the Tobin Lake Study utilizes the ecosystem approach to develop a chemical/analytical protocol which is consistent with biological evidence of toxic stress. Preliminary evidence indicates that the incidence of deformities is relatively high (ca. 20%) at some sites in the lake. The relationship between rates and severity of deformities is being examined at the present time, while technical preparation of material from the remaining sites sampled during February 1980 is continuing. A number of toxic chemicals including dioxins, xylenes, PCB's and other industrial waste products have been identified in the sediment fractions thus far and may be contributing to the stress evident in the chironomid fauna.

### Fluvial Transport of Nutrient and Contaminants in the Bow and Oldman Rivers

This study, initiated in 1980 at Queen's University, under TCMP, IWD and NSERC funding, focusses on spatial and temporal patterns of phosphorus and contaminants (heavy metals including mercury, organo-chlorine pesticides and chlorobenzenes) over some six hundred kilometers of river downstream from a major urban point source (Calgary on the Bow River and Lethbridge on the Oldman River). Sampling reflects

time-of-travel under typical flow regimes of these prairie rivers (spring, summer, fall) and addresses changing chemical phases associated with solution, suspended sediment, and in-stream plant biomass. Representative irrigation return flows were sampled to characterize the range of nonpoint source contributions to these receiving rivers. Speciation of sediment-associated metals in irrigation return flows indicates that the majority of metals flux is biologically unavailable. River data show well-defined downstream and seasonal patterns of phosphorus and contaminant forms. Figure 3 is one such pattern for organochlorine compounds which indicates preferential accumulation on plant and/or suspended sediment, and casts doubt upon the interpretation of OC determinations from total water samples. Similar data, expressed as concentration factors are now available for phosphorus and metals. Data from this study, together with similar information from other rivers in western Canada, have been used to generate calibration curves for continuous-flow centrifuge recovery of suspended sediment from fluvial systems.

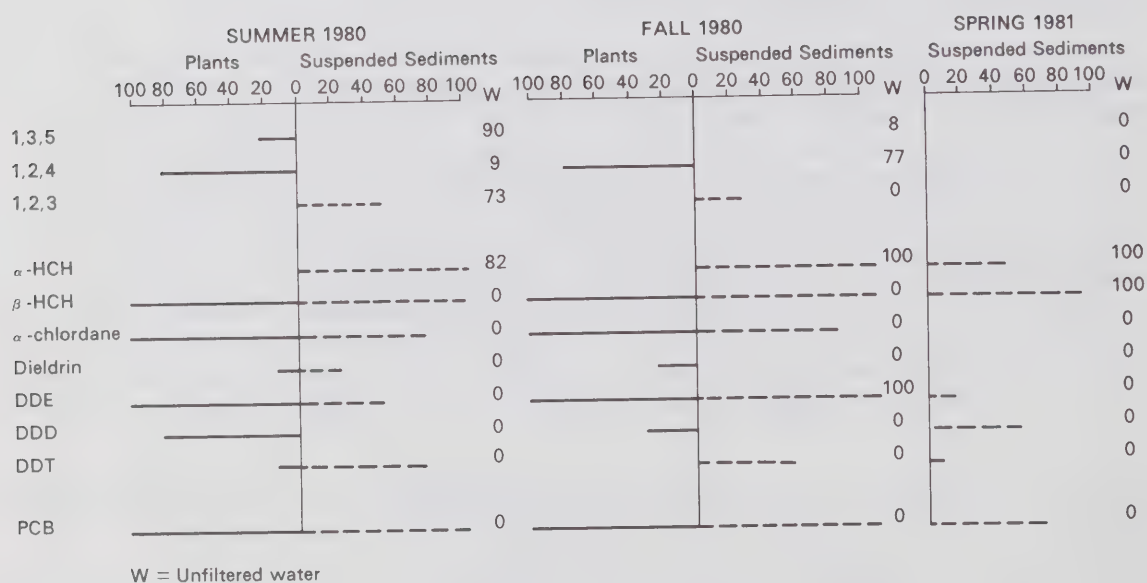


Figure 3. Seasonal phase distributions of chlorobenzenes, organochlorine pesticides and PCBs for the Bow and Oldman Rivers, Alberta. The percentage of all samples containing detectable quantities of each compound is indicated. Plant matter was not sufficiently available in the spring.

## PACIFIC AND YUKON REGION

The offices and laboratories of the Pacific and Yukon Region are located at the West Vancouver laboratory complex (formerly the Pacific Environment Institute) on Marine Drive in West Vancouver, B.C. Pacific and Yukon Region Branch is responsible for conducting applied research related to regional water management problems. Its primary thrust is in the application of interdisciplinary limnological studies that lead to a better understanding of the way the regional lakes work and, ultimately, to the development of a predictive model of the ecological response of regional limnologic systems to the application or removal of anthropogenic environmental stresses. Common stresses include: the impact of nutrient-rich effluents, particularly those of urban or industrial origin; the impact and influence of substances that range from placer-mine waste, acidic and metal-rich mine drainage and tailings, to herbicide breakdown products; reservoir construction and operation related to hydro-electric power generation; and inter- or intra-drainage-basin diversion schemes.

Intensive orogenic, igneous intrusive and volcanic activity in the past, combined with the erosion and deposition associated with extensive glaciation during the Pleistocene age, have resulted in a rugged, mountainous region that is unique in Canada. Consequently, the limnic systems of the P&Y Region, and the limnological processes operating in them, are specific to this area, and the transfer of conclusions drawn from the study of lake systems elsewhere in Canada is at best only tenuous. While the transfer of conclusions between systems within the region is possible as generalizations, each system has fine details in its response to environmental stresses that require site-specific research. Specific water resource management options can only be considered on the basis of the results of site- or process-specific studies. However, as an increasing number of regional limnic systems are studied and understood, broad generalizations can be made (with increasing prospects for accuracy) that are applicable to other systems within the Region.

Three major programs were concluded by the Branch in the 1980-81 period, and two new ones were initiated. The large-scale study of the effects of upstream impoundments on the limnology of Kootenay Lake was completed and the report was published; and the study of the degradation and dispersal of the herbicide 2,4-D in the Okanagan lakes was also completed and a report submitted. Although papers to be submitted to scientific journals are still being prepared, the management report on the survey and research into the limnological trends in Wood Lake, B.C. was completed, and a report is due to be released early in 1982. An investigation into the nutrient controls and the growth rates of benthic algae in the Thompson River, using an experimental design that included the development and use of flowing troughs, was made in the winters of 1980-1981. A report on this work was released in 1981, and the study has, in cooperation with Weyerhaeuser Canada, been enlarged and extended for another 3 to 4 years. Finally, the Branch has



begun an extensive, long-term project to study the limnology of the large lakes at the head of the Yukon River. Reports on this study will be presented sporadically during the course of the project.

### Kootenay Lake

Kootenay Lake is a medium residence time lake in which the physical and chemical characteristics of the water masses are strongly influenced by the two major inflowing rivers (Fig. 1). Annual patterns of circulation and mixing (Fig. 2) are strongly affected by the river inflows but are significantly modified by other mechanisms within the lake, such as surface-driven processes and internal wave dynamics. However, the principal controls on biological productivity are those influencing the supply and availability of nutrients to the phytoplankton rather than the direct effects of riverine flow such as washout or the euphotic-zone to mixing-depth ratios (Fig. 3).

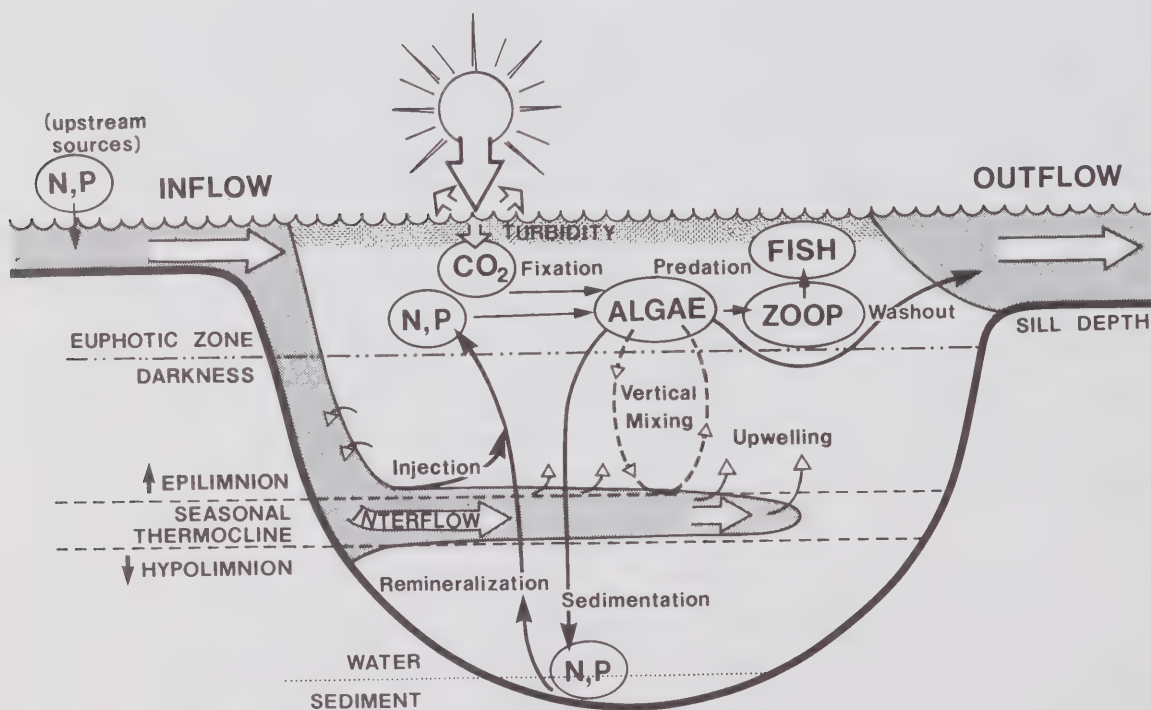


Figure 1. Schematic diagram of processes influencing the ecology of Kootenay Lake.

During winter, the inflowing rivers flow either along the bottom or at some intermediate depth and supply nutrients to the general mass of the lake. Between winter and spring the lake is essentially well mixed and nutrients are distributed throughout the water column. With the onset of stratification in spring, some nutrients are trapped

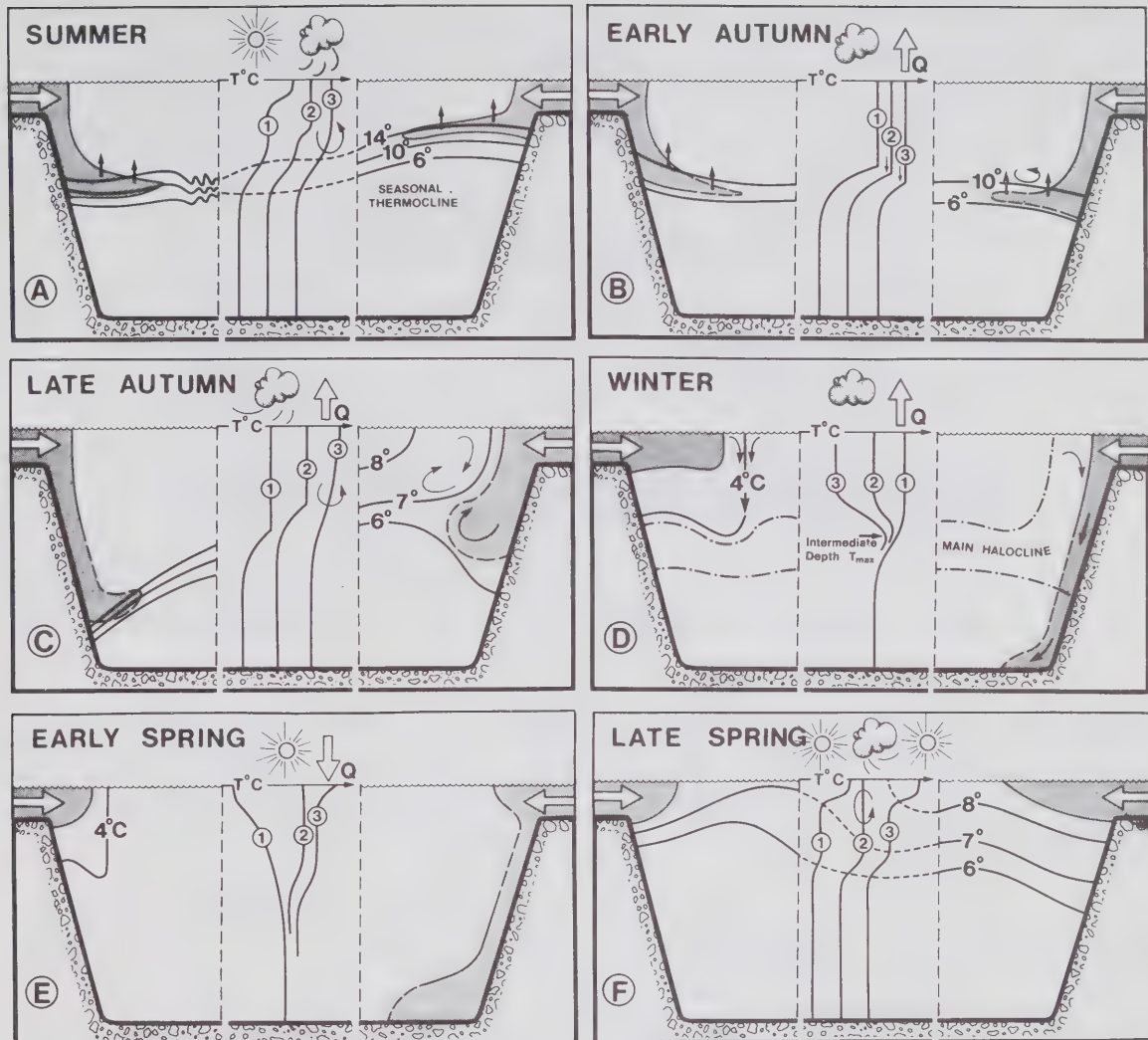


Figure 2. Schematic representations of seasonal circulation and mixing patterns in Kootenay Lake: A - summer; B - early autumn; C - late autumn; D - winter; E - early spring; F - late spring. Shaded areas denote the two major rivers. Solid lines reflect the relative positions of isotherms; their vertical displacements depict internal seiche motions. Inserted temperature profiles show sequential changes in thermal structure associated with stratification and mixing processes.

in the new epilimnion and provide a starting source of food for early phytoplankton (diatom) growth. At this time of the year, the river inflows are large and confined to the epilimnion. Although they maintain a steady nutrient supply, they also increase turbidity in the euphotic zone. For a short period phytoplankton growth is controlled by deep mixing and lessened light penetration. Once the thermocline is established, however, transfer of nutrients from the hypolimnion to the

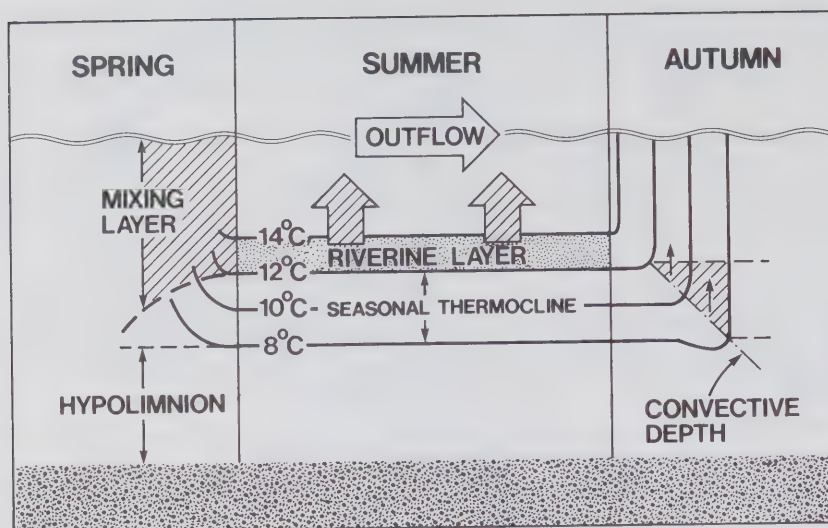


Figure 3. Schematic diagram of the compartmentalisation of the nutrient supply on the basis of physical processes controlling distribution at various times of the growing season in Kootenay Lake.

epilimnion is prevented and the rest of the summer's nutrient supply comes from the rivers. Subsequently, the supply of nutrients is depleted to a point where phytoplankton growth is controlled by the levels and ratios of the major essential nutrients, phosphorus and nitrogen.

During the last 30 years, the supply to the lake of the two primary nutrients, nitrogen (N) and phosphorus (P) has changed drastically. As a result of population growth and, in particular, the

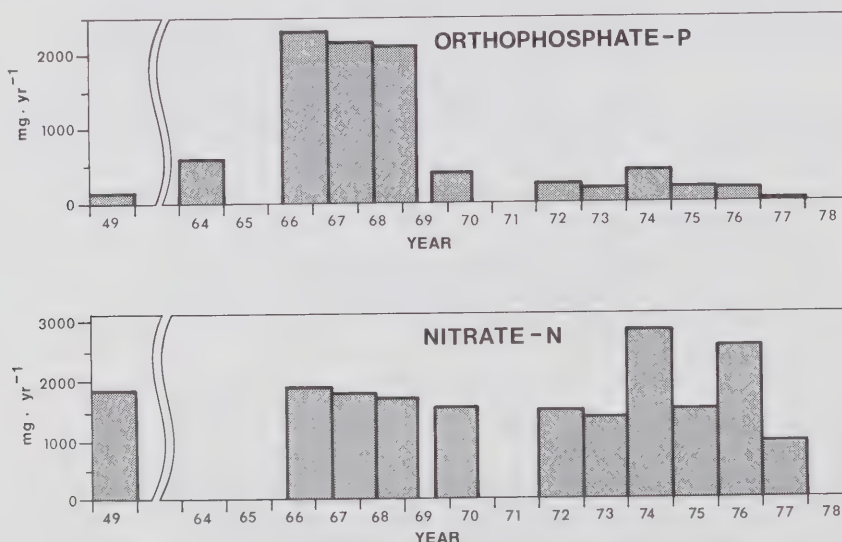


Figure 4. Long-term trends in the loadings of the orthophosphate-p and nitrate-N into Kootenay Lake.



upstream release of effluent from a phosphate fertilizer plant, P loadings to the lake increased 15-fold between 1950 and the late 1960's and N loadings doubled (Fig. 4-5). This process of eutrophication, or over-fertilization, was reversed in the late 1960's by pollution abatement measures at the fertilizer plant, so that nutrient loadings declined throughout the 1970's.

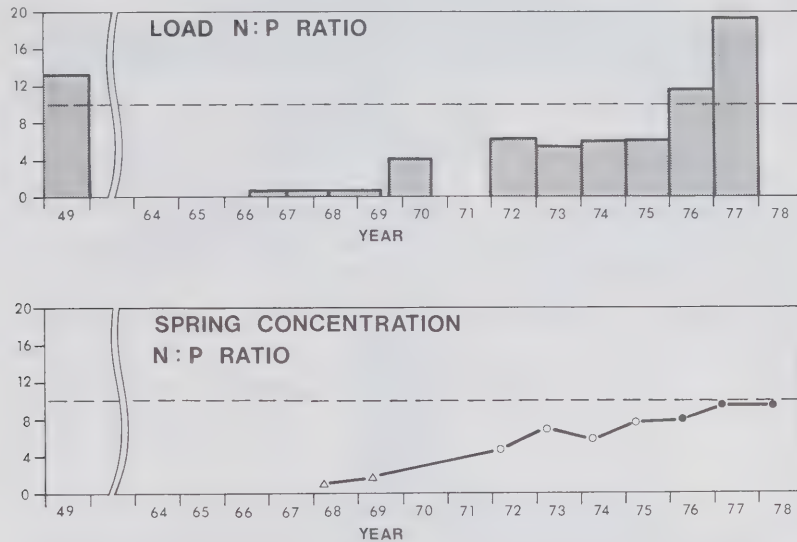


Figure 5. Long-term trends in the N/P ratios of the loadings and spring overturn concentrations in Kootenay Lake. Open triangles represent data from Taylor (1972); open circles, data from Nordin and Crozier (in prep.); solid circles from this report.

Before and during the period of declining nutrient loadings, the Duncan and Libby dams were constructed on the two major influent rivers. Their principal effects have been to alter the timing and shape of the annual hydrograph, and to cause a further reduction of nutrient supplies to the phytoplankton (Fig. 6). Several processes are shown to be involved, including nutrient retention in the reservoirs behind the dams, enhancement of nutrient "stripping" from the rivers below the dams, and a shift in nutrient loadings from spring and summer to winter. This shift has resulted from the impoundment of the spring freshet for subsequent release in winter, and from the operation of a depth-selective system for water withdrawal at the Libby Dam. Most of the nutrient losses caused by the dams occur in the Libby Reservoir and in the Kootenai (spelled Kootenay in Canada) River between Libby Dam and the lake.

The fluctuations in nutrient supply have affected both the phytoplankton and the zooplankton that feed on them (Fig. 7). Between 1950 and 1970, the levels of both increased at least two- to four-fold and the numbers of blue-green algae increased to nuisance proportions. With the reduction of nutrients during the 1970's, however, the levels of phytoplankton and zooplankton again declined and the blooms of blue-green algae diminished in magnitude.



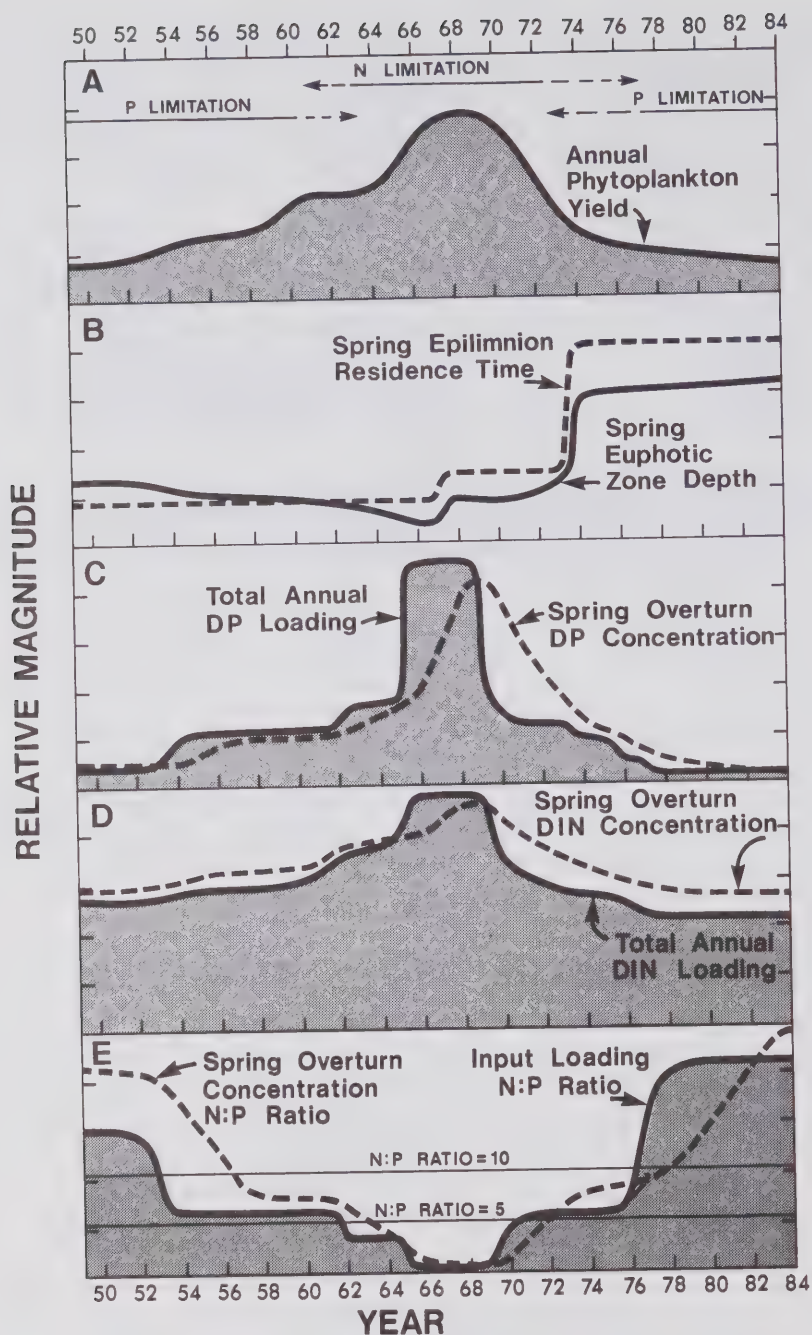


Figure 6. Idealized lakewide trends in important limnological characteristics in Kootenay Lake between 1949 and 1984. Relative changes of all parameters are to scale for direct comparison: A - annual phytoplankton yields; B - spring epilimnion residence times and spring euphotic-zone depths; C - total annual dissolved phosphorus (DP) loadings and DP spring overturn concentrations; D - total annual dissolved inorganic nitrogen (DIN) loadings and DIN spring overturn concentrations; E - N/P ratios of input loadings and of spring overturn concentrations.

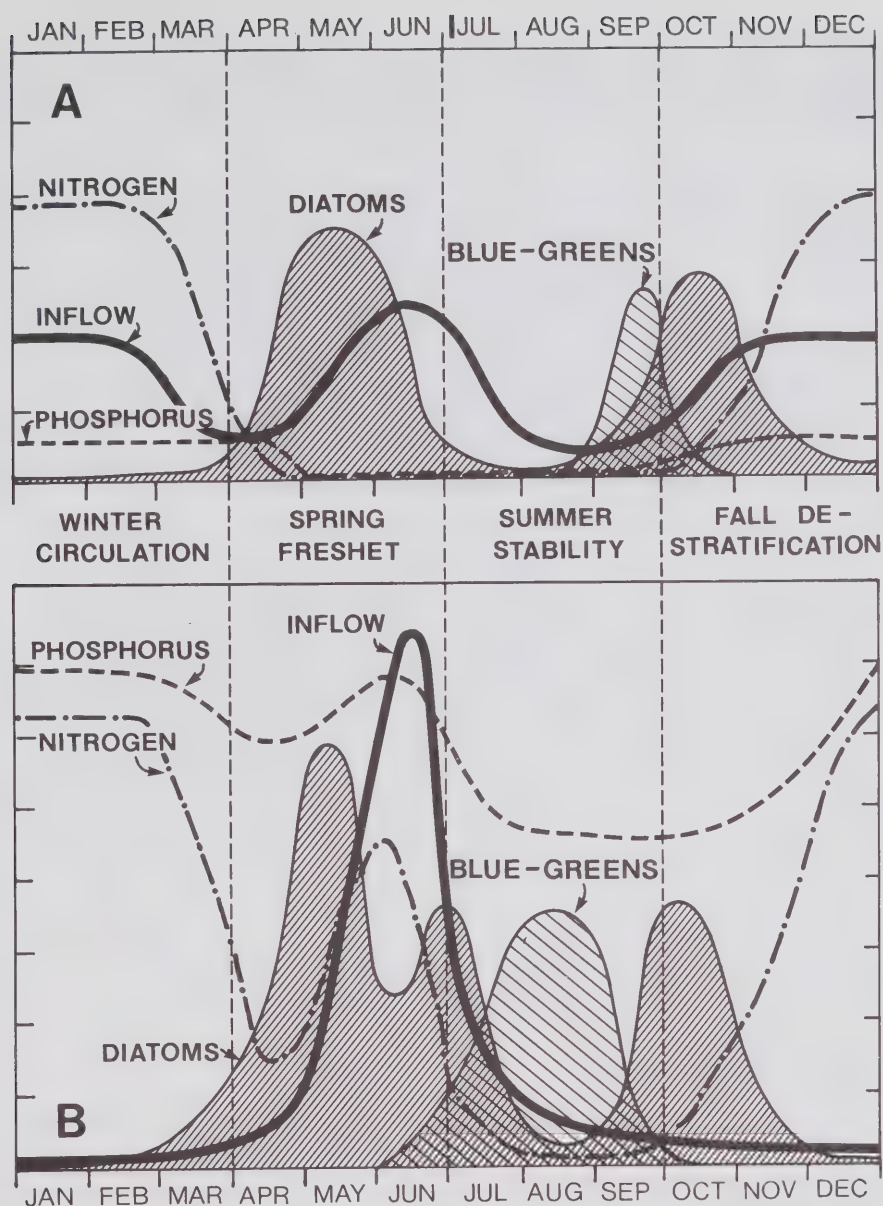


Figure 7. Schematic diagram of seasonal patterns of streamflow, nutrient concentrations and phytoplankton biomass in Kootenay Lake: A - 1977 (post-dam); B - in 1966 (pre-dam).

The decreases in nutrients and biological production are not yet complete. Physical and chemical time lags have prevented the lake from reaching equilibrium with its reduced supply of nutrients. Equilibrium should occur in the mid-1980's, at which time the phytoplankton and zooplankton will likely return to levels at or below those of 1950.

The relative effect of the dams in decreasing the biological production of the lake will vary over time. In 1977, between 25% and

50% of the decreases could be assigned to the presence of the dams. By 1985, however, the levels of phytoplankton and zooplankton in the lake are predicted to be at most about half of what they would be if the dams had not been built.

The ultimate effects of reduced populations of phytoplankton and zooplankton on the fish in the main basin of Kootenay Lake are unknown. However, if further research shows that the major species of fish are limited by food supply and not by other factors, such as the availability of spawning or rearing habitat, then the fish population could decrease by an amount similar to that predicted for the phytoplankton. The situation is complicated by the presence of mysids. Although unproven, it is possible that mysids may be able to compete both with the zooplankton for algae and with the juvenile fish (particularly kokanee) for zooplankton, thereby causing a further decline in fish numbers.

The West Arm, in contrast with the main lake, is a rapidly flushed system in which the fish, particularly the kokanee, feed on various insects and on plankton washed in from the main lake. Average kokanee sizes have increased greatly in recent years owing to increased grazing on mysids. The study confirmed earlier suggestions that the mysids are washed into the West Arm from the main lake. This raises the possibility that reductions in discharge rates and water levels in summer caused by the dams, together with a decline in the numbers of mysids in the main lake, could reduce the supply of mysids to the West Arm. The mean size of the kokanee, and hence their desirability to anglers, might then decline. It is not clear at present, however, whether the export of mysids from the main lake is controlled by water discharge or by other ecological factors, nor is it known whether the mysids will decrease in numbers after nutrient equilibrium is reached.

## 2,4-D in Okanagan Lakes

In 1976, the British Columbia Ministry of Environment began experimenting with the use of the herbicide 2,4-dichlorophenoxyacetic acid (2,4-D), as one part of a coordinated program aimed at controlling the abundance and spread of Eurasian water milfoil (Myriophyllum spicatum) in the Okanagan Valley lakes of British Columbia. The initial success obtained with Aqua-Kleen 20, a butoxyethanol ester (BEE) formulation of 2,4-D, led to a gradually expanded treatment program in Okanagan Lake in 1977 and 1978. This expansion generated strong public concern about the possibility of adverse environmental effects of 2,4-D treatments in the Okanagan Valley lakes. The questions posed ranged from those of a general nature about harm to non-target biota, long-term persistence of 2,4-D residues in the sediment, and contamination of untreated areas, to specific ones regarding the adequacy of certain aspects of the environmental monitoring program during and after herbicide treatment periods.



In response to this regional problem, and to the growing awareness of the potential magnitude and impact of milfoil infestations nationwide, the federal Department of the Environment established a national aquatic weed research program within the NWRI. The program, begun in 1978, had two major objectives. The first was long-term research to be carried out at the Canada Centre for Inland Waters in Burlington, Ontario, on alternatives to herbicide usage for controlling aquatic weeds. The second was a short-term study by the P&Y regional branch of NWRI directed at the public concerns for the environmental safety of the provincial 2,4-D treatment program in the Okanagan Valley lakes. It was hoped the latter would provide an independent evaluation of some of the more contentious issues. The unpublished Regional IWD report describes the results and conclusions from the regional, short-term study.

Analytical methods for 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4-D-butoxyethanol ester (2,4-D BEE) and 2,4-dichlorophenol (2,4-DP) were evaluated and procedures were developed for sediment analysis. The long-term persistence of these three herbicide residues was examined in the sediments of Wood and Kalamalka Lakes, B.C., which had been treated with Aqua-Kleen 20 in 1979. In both lakes, 2,4-D was the longest lived of the three forms. Undetectable levels were reached in 120 days, after treatment, in Wood Lake and in about 180 days in Kalamalka Lake. 2,4-D BEE and 2,4-DP dropped below detection after 54-77 days except in Kalamalka Lake where the ester persisted longer, about 72-125 days. These data confirm previous studies that 2,4-D, a polar herbicide, does not persist or accumulate beyond the season of application.

The presence and transport of 2,4-D BEE and 2,4-D in the microlayer at the air-water interface were also examined, both in the field and in laboratory aquaria. Herbicides in the microlayer in both Wood and Kalamalka lakes were spread over large untreated areas within 24 hrs of application. However, the concentrations were very low ( $<1 \mu\text{g.L}^{-1}$ ) and could only account for a small percentage of the total transport of 2,4-D residues out of treatment areas. Measurable levels of 2,4-D BEE and 2,4-D in the microlayer persisted for less than two weeks after application in both lakes (Wood Lake, 7 days; Kalamalka Lake, 11 days).

Several processes influencing concentration and short-term persistence of 2,4-D BEE were examined in laboratory experiments. The theoretical half-lives of 2,4-D BEE under different temperature and pH conditions were confirmed empirically. At temperature and pH values typical of the Okanagan lakes in early summer, the half-life of the butoxyethanol ester form of 2,4-D is 5 to 16 hrs. Release of 2,4-D BEE from Aqua-Kleen bentonite granules into bulk-water is influenced by sediment type. In all cases examined, slow release and rapid hydrolysis prevented 2,4-D BEE concentrations from exceeding  $70 \mu\text{g.L}^{-1}$ . This concentration is below values demonstrated to be harmful to salmon and trout.



## Thompson River - Benthic Algae

The final report of the Joint Thompson River Federal-Provincial Task Force in 1976 concluded that phosphorus loadings from the Weyerhaeuser Canada pulp mill and the City of Kamloops sewage treatment plant were responsible for the excessive accumulation of benthic algae in the Thompson River below Kamloops Lake (Fig. 8). Despite the many compelling facts amassed during the two-year study, all the evidence implicating phosphorus as the causative agent in the benthic algal blooms at Savona and Walachin was indirect. No direct data were available to indicate whether 1) algal growth rates were higher at Savona than in the Upper Thompson River, or 2) whether the phosphorus nutrition of benthic algae at Savona was better than in the Upper Thompson River.

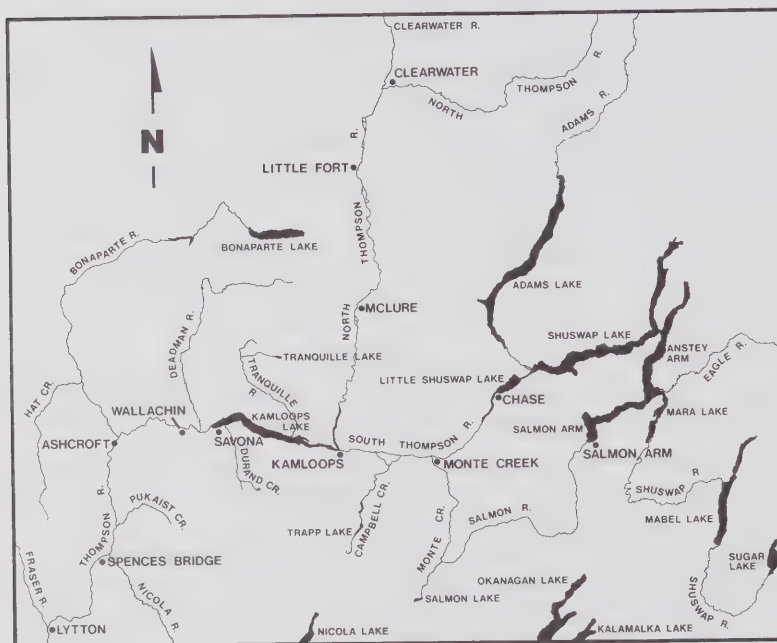


Figure 8. Location map of the Thompson River Basin.

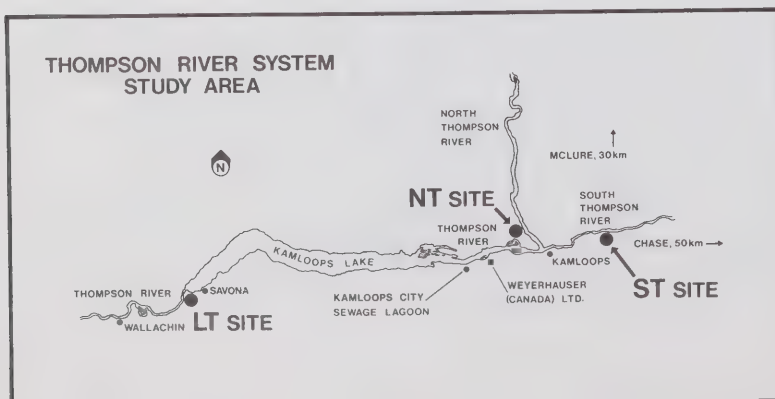


Figure 9. Location map of the study area, showing the trough sites on the North (NT), South (ST) and Lower Thompson (LT) rivers.

To obtain these data, and to verify the conclusions of the Task Force, IWD entered into an agreement with Weyerhaeuser Canada Ltd. in July 1979 to undertake a joint research project employing an experimental flowing-trough methodology. The original contract was extended in September of 1980 to permit a second winter of study. Although the regional IWD report summarizes the results and conclusions of the work in both years, it was originally prepared for presentation to Weyerhaeuser Canada Ltd. under the terms of the research contract and therefore provides only an overview of the study. The detailed results will be published in scientific journals.

Using continuous-flow troughs, the growth rates and phosphorus nutrition of benthic diatom communities in the North and South Thompson above the pulp mill and the sewage facility were compared to periphyton communities in the Lower Thompson River below Kamloops Lake (Fig. 9). In both years, the phosphorus concentrations in the Lower Thompson River were significantly higher than in either the North or South Thompson Rivers. Likewise, physiological indicators of phosphorus deficiency in algae clearly demonstrated that diatoms in the Lower Thompson River had much better phosphorus nutrition than those upstream of Kamloops (Fig. 10). Estimates of algal growth rate confirmed that the benthic algae below Kamloops Lake were also growing faster.

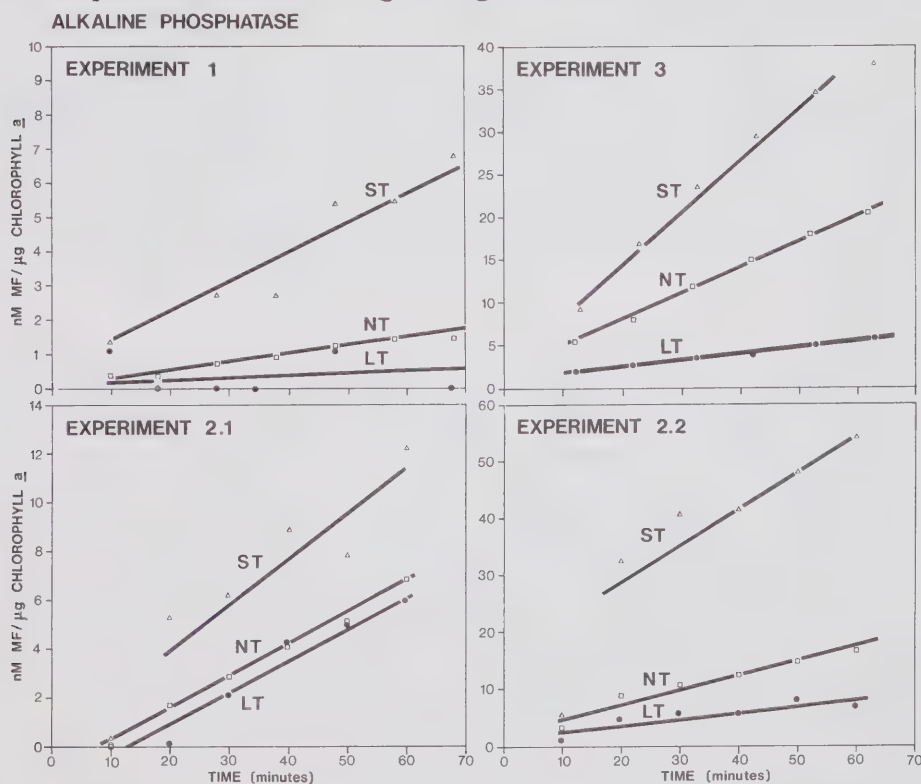


Figure 10. Time-course curves of alkaline phosphatase activity of attached diatom communities in experimental, continuous flow troughs on the North Thompson (NT), South Thompson (ST), and Lower Thompson (LT) Rivers.

### Wood Lake Limnology

In recent years there have been increasing expressions of public concern about an apparent deterioration in the water quality of Wood Lake in the Okanagan Valley, B.C. In response, the Okanagan Basin Implementation Board (OBIB) established a Federal-Provincial working group to evaluate restoration methods for improving the water quality of Wood Lake. As the result of a review of previous investigations of the lake, it became apparent that large gaps in the data and fundamental differences in interpretation existed, and further limnological research was needed before an assessment of restoration alternatives could proceed. To this end the Regional NWRI Branch with the financial assistance of OBIB, undertook a study of Wood Lake between April 1980 and March 1981. The results of the study indicate that in 1980 the lake was mildly eutrophic. However, several indicators (water clarity, oxygen depletion rates, phytoplankton biomass and species succession) suggest that there has been a slight improvement during the last decade. A possible explanation is higher nitrate levels in the spring since 1975. Future increases in nitrate levels, by intentional additions in the spring or early summer, may further improve the lake's condition. The use of mechanical aerators (with or without destratification), however, is not recommended because of their prohibitive cost and possible adverse ecological effects.

A very detailed set of physical limnology observations were made on Wood Lake during the summer of 1981. Reduction and interpretation of this data are proceeding toward the presentation of a data report, and the publication of papers describing the temporal and spatial variability of physical parameters and the physical mechanism responsible for dispersion and transport of nutrients in Wood Lake.

### Yukon Limnology

Hydroelectric developments in northern B.C. and the Yukon over the next two decades will create new reservoirs or alter natural lakes, with secondary impacts in both cases on downstream river quality. Mining and industrial developments may also affect river, lake and reservoir quality. However, almost nothing is known about the limnology of these northern lakes and, given their unique characteristics, extrapolations from knowledge of southern lakes may be inaccurate. Without better knowledge of the processes controlling the dynamics of these lakes, predictions of their environmental sensitivity, or insensitivity, to development may be misleading or impossible. The objective, therefore, is to document the limnological characteristics of typical large northern lakes and provide predictive generalizations about their sensitivity to environmental alterations, if possible through simulation modelling. The Yukon River Basin headwater lakes (Fig. 11) are regarded as typical examples of the northern intermontane lakes.



Figure 11. The headwater lakes of the Yukon River Basin in Southern Yukon Territory.

The project consists of selective field studies, synthesis of results in terms of specific hypotheses about ecological control, and of numerical modelling. The field work is organized by discipline into three sequential, but overlapping, phases: physics/sedimentology, chemistry, and biology. Within each phase there will be first reconnaissance and survey work, followed by specific studies of important processes from which testable hypotheses are formulated for use in the next phase. This gives maximum flexibility to modify the project as results dictate. Because of logistics and cost, data will not be obtained by conventional monitoring, but by serial measurements along a transect from Atlin Lake through Tagish and Marsh Lakes to Lake LaBerge. Transect data will be augmented by conventional sampling of Lake LaBerge with monitor and moored instrumentation. Modelling work will focus initially on physical processes with assistance from NWRI-HQ. Existing models will be modified for use in ice-covered lakes and tested against measured field data.



So far the 5-year project plan has been worked out in detail and the first exploratory field year of the physics/sedimentology phase is complete. From field soundings, bathymetric maps and morphometric parameters of Lakes LaBerge, Marsh, Tagish, and most of Bennett, have been prepared. Surficial sediment samples were collected from Lake LaBerge and are being analysed. Transect surveys of temperature and conductivity were carried out both in summer and winter; special sampling methods and instruments required for these surveys were developed and tested. The completion of the first field year confirmed the feasibility of the study design, and only minor refinements to the basic plan have been necessary.

## **PUBLICATIONS**



### Senior Scientist

- R.A. Vollenweider     "The Loading Concept as Basis for Controlling  
J.J. Kerekes           Eutrophication Philosophy and Preliminary Results of  
the OECD Program on Eutrophication." Prog. Wat.  
Tec. Vol. 12, Norway. pp 5-18, 1980.
- R.A. Vollenweider     "Organization for Economic Cooperation and  
J.J. Kerekes           Development, Cooperative Program on Monitoring of  
Inland Waters (Eutrophication Control)." Synthesis  
Report, April 1980. 290 p.
- R.A. Vollenweider     (with members of the Technical Bureau, OECD  
J.J. Kerekes           Cooperative Program on Eutrophication.) "Background  
and Summary Results of the OECD Cooperative Program  
on Monitoring of Inland Waters." Proc. of  
International Symp. on Inland Waters and Lake  
Restoration, 1980. Portland, Maine. EPA  
440/5-81-010, pp 25-36.
- R.A. Vollenweider     Comments on paper by W.T. Edmondson and  
J.T. Lehmann, "The Effect of Changes in the Nutrient  
Income on the Condition of Lake Washington."  
Invited by the Editor of Limnology and Oceanography  
to comment. 1981.
- R.A. Vollenweider     "Eutrophication - A Global Problem." WHO Water  
Quality Bulletin. Vol. 6, No. 3, Environment  
Canada. ISSN 0706-8158, p. 59-62, 89-90. 1981.
- R.A. Vollenweider     "Statistical Models for Predicting Hypolimnetic  
L.L. Janus           Oxygen Depletion Rates." Mem. Ist. Ital. Idrobiol.  
(In press.) 1981.
- L.L. Janus           "OECD Cooperative Program on Monitoring of Inland  
R.A. Vollenweider     Waters." Summary Report, Canadian Contribution,  
Scientific Series No. 131, Environment Canada, 390  
p. 1981.
- R.A. Vollenweider     "Report on the Activities of OECD in the Field of  
Eutrophication Studies and Eutrophication Control."  
Presented at I.W.S.A. Specialized Conference on  
Eutrophication and Water Supply. Vienna, October,  
1981. (In press.)
- R.A. Vollenweider     Concluding Remarks to the I.W.S.A. Specialised  
Conference on Eutrophication and Water Supply.  
Vienna, October, 1981. In press.



G.P. Harris  
R.A. Vollenweider "Paleolimnological evidence of early eutrophication in Lake Erie." Canadian Journal of Fisheries and Aquatic Sciences. Vol. 39, No. 4, 618-626. 1982.

R.A. Vollenweider "Energy, pollution and the disruption of environmental equilibria, or 'L'Apprenti Sorcier." Proc. Italian Congress on International Days of Biology: Ways to Survival. Organized by Italian League of Professional Biologists. Naples, Italy, March, 1982. (In press.)

#### Habitat Studies (ECS-552)

H.L. Golterman  
P.G. Sly  
R.L. Thomas "Study of the Relationship between Water Quality and Sediment Transport; A Guide for the Collection and Interpretation of Sediment Quality Data." Tech. Papers in Hydrology Series, UNESCO, Paris. (In press.)

P.G. Sly  
(Editor) Proceedings Second International Symposium on Sediment/Freshwater Interaction. Kingston, Ontario 1981. Junk Publishing, The Hague. (In press.)

P.G. Sly  
R.L. Thomas  
B.R. Pelletier "Comparison of Sediment Energy-texture Relationships Marine and Lacustrine Environments." In Proc. 2nd International Sediment/Freshwater Symposium, Kingston, Ont. (In press.)

P.G. Sly  
R.L. Thomas  
B.R. Pelletier "Interpretation of Moment Measures Derived from Water-Lain Sediments." Sedimentology. Accepted for publication.

P.G. Sly  
R.G. Sandilands Report of the Hamilton-Scourge Survey. (In preparation.)

P.G. Sly  
C. Widmer "Lake Trout Habitat in Seneca Lake, N.Y." (In preparation.)

#### Environmental Contaminants Division

R.M. Baxter "Microbial Metabolism of Chlorinated Biphenyls: A Review." NWRI Report. 1981.

J.H. Carey  
M.E. Fox  
B.G. Brownlee  
J. Metcalfe  
R. Tkacz  
L. Coletta  
G. MacInnis "Occurrence of Nonyl Phenol Surface Slicks in Canagagigue Creek." NWRI Report. 1982.

- M.D. Baker  
P.T.S. Wong  
Y.K. Chau  
C.I. Mayfield
- "Methylation of Pb, Hg, As, Se in the Acidic Aquatic Environment." Int. Conf. Heavy Metals in the Environment, pp. 645-648. 1981.
- Y.K. Chau  
P.T.S. Wong  
O. Kramar  
G.A. Bengert
- "Methylation of Tin Compounds in the Aquatic Environment." Int. Conf. Heavy Metals in the Environment, pp. 641-644. 1981.
- F.E. Brinckman  
R.H. Fish  
(Editors)
- "Some Environmental Aspects of Organoarsenic, Lead and Tin." NBS Special Publication No. 618  
"Environmental Speciation Monitoring Needs for Trace Metal-Containing Substances from Energy-Related Processes." pp. 65-80. 1981.
- P.T.S. Wong  
Y.K. Chau  
O. Kramar  
G.A. Bengert
- "Accumulation and Dupuration of Tetramethyllead by Rainbow Trout." Wat. Res., 15, pp. 621-625. 1981.
- R.W. Durham
- "Potential Impacts of Nuclear Power Development in the Great Lakes Basin." IJC Science Advisory Board Document, 1981.
- R.W. Durham  
G.H. Jamro
- "Great Lakes Surveillance, 1980." NWRI Report. 1981.
- R.W. Durham  
S.R. Joshi
- "Concentrations of Radionuclides in Lake Ontario Water from Measurements on Water Treatment Plant Sludges." Water Research, 15, pp. 83-86. 1981.
- R.W. Durham  
S.R. Joshi
- "Sedimentation rates in Western Nipigon Bay, Lake Superior, Using the Lead-210 Method." Science of the Total Environment, 22, pp. 51-59. 1981.
- R.W. Durham  
S.R. Joshi
- "The Rates of Sediment Accumulation in Oshawa Second Marsh by <sup>210</sup>Pb and <sup>137</sup>Cs Dating of Cores." Appendix 3, Oshawa Second Marsh Baseline Study, Environment Canada Interim Report. 1981.
- R.W. Durham  
S.R. Joshi
- "Lead-210 Dating of Sediments from Some Northern Ontario Lakes." Proceedings of Quaternary Dating Methods Symposium, York University, Toronto, May 1981. 1982.
- M.E. Fox  
J.H. Carey  
B.G. Oliver
- "Relationships between Levels of Organochlorine Contaminants in Niagara River Suspended Solids and Lake Ontario Western Basin Sediments and Benthos." To be presented at XXV IAGLR Conference, May 1982 and to be submitted for publication to J. Great Lakes Research. 1982.

- D.S. Jeffries  
R. Semkin "Basin Description and Information Pertinent to Mass Balance Studies of the Turkey Lakes Watershed." NWRI Report, 34 p. January 1982.
- D.S. Jeffries  
R. Semkin "Changes in Stream and Lake Acidity During Snowmelt in the Turkey Lakes Watershed." Manuscript in preparation for submission to J. Great Lakes Res.
- D.S. Jeffries  
W.R. Snyder "Variations in the Chemical Composition of the Snowpack and Associated Meltwater in Central Ontario." Proc. of 38th Eastern Snow Conference, Syracuse, N.Y. (In press.) 1981.
- S.R. Joshi "Airborne Radioactive Materials and Plants: A Review." Science of the Total Environment. (Accepted for publication.) 1982.
- M.E. Comba  
K.L.E. Kaiser "Determination of Volatile Contaminants in Water at the ng.L<sup>-1</sup> Level." NWRI Report. 1982.
- M. Dickman  
Y. Prescott  
K.L.E. Kaiser "Variations in the Aquatic Vegetation of the Welland River (Ontario, Canada) Above and Below an Industrial Waste Discharge." To be submitted to Sci. of the Total Environ. 1982.
- D.G. Dixon  
P.V. Hodson  
K.L.E. Kaiser "The Use of LD<sub>50</sub> Determination by Intraperitoneal Injection as a Rapid Method for Initial Estimates of Pollutant Toxicity to Fish." In Proc. of the 8th Annual Aquatic Toxicity Workshop, Guelph, Ontario, Nov. 2-4, 1981. Fisheries and Marine Service Technical Bulletin. (In press.) 1982.
- K.L.E. Kaiser  
M.E. Comba "Volatile Contaminants in the Lower Niagara River." NWRI Report, 1982.
- K.L.E. Kaiser  
M.E. Comba "Volatile Contaminants in the Welland River Watershed." NWRI Report, 1982.
- K.L.E. Kaiser  
I. Valdmanis "Apparent Octanol-Water Partition Coefficients of Pentachlorophenol as Function of the pH." Can. J. Chem. (Submitted.) 1982.
- D.L. Liu "A Rapid Biochemical Test for Measuring Chemical Toxicity." Bull. Environ. Contam. Toxicol. 26, pp. 145-149. 1981.
- D.L. Liu "Biodegradation of Arochlor 1221 Type PCBs in Sewage Wastewater." Bull. Environ. Contam. Toxicol. 27, pp. 695-703. 1981.

- D.L. Liu "Biodegradation of p-Nitrophenol in Aquatic Environment." Eau de Québec. 14, pp. 212-213. 1981.
- D.L. Liu "An Improved Agar Plate Method for Rapid Assessment of Chemical Inhibition to Microbial Populations." Bull. Environ. Contam. Toxicol. 27, pp. 289-294. 1981.
- K. Kwasniewska
- D.L. Liu "A Field Method for Determining the Chemical and Biological Activity of Sediments." Wat. Res. 15, pp. 353-359. 1981.
- W.M.J. Strachan
- D.L. Liu "Determination of the Biodegradability of Organic Compounds." Environ. Sci. Technol. 15, pp. 788-793. 1981.
- W.M.J. Strachan
- K. Thomson
- K. Kwasniewska
- D.L. Liu "Biodegradation of Pentachlorophenol in a Simulated Aquatic Environment." Bull. Environ. Contam. Toxicol. 26, pp. 85-90. 1981.
- K. Thomson
- W.M.J. Strachan
- D.L. Liu "Biodegradation of Carbaryl in Simulated Aquatic Environment." Bull. Environ. Contam. Toxicol. 27, pp. 412-417. 1981.
- K. Thomson
- W.M.J. Strachan
- H. Beach "Trace Metal Availability in Oshawa Second Marsh." NWRI Report. 1981.
- K.R. Lum
- K.V. Dechert
- J.L. Fraser "The Availability of Elements of Environmental Importance in Incinerated Sludge Ash." Environ. Sci. Technol. (Submitted.) 1982.
- K.R. Lum
- J.K. Leslie "A Study of Dissolved and Particulate Trace Metals in Lake Erie." NWRI Report. 1981.
- K.R. Lum
- K.R. Lum "Dissolved and Particulate Trace Metals in Meltwater from the Rhône Glacier." Schweiz. Z. Hydrol. (In press.) 1981.
- K.R. Lum
- "The Potential Availability of P, Al, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn in Urban Particulate Matter." Environ. Technol. Letts., 3, pp. 57-62. 1982.
- J.S. Betteridge
- R.R. Macdonald
- K.R. Lum "The Use of a Microcomputer for Data Acquisition and Treatment for Electrothermal Atomization AAS." NWRI Report. 1982.
- B. Radziuk
- G. MacIsaac
- G. and I. Singh



- G. MacIsaac  
R. Karim  
J.S. Betteridge  
R.R. Macdonald  
K.R. Lum
- "The Chemical Form and Potential Availability of Trace Metals in the Southeastern Part of Hamilton Harbour." NWRI Report. 1981.
- E. Halfon  
R.J. Maguire
- "Distribution et Transformation du Fénitrothion Épandu sur un Étang: Modélisation dans des Conditions d'Incertitude." Eau du Québec, 14, 216-220. 1981.
- R.J. Maguire  
H. Huneault
- "Determination of Butyltin Species in Water by Gas Chromatography with Flame Photometric Detection." J. Chromatogr. 209, pp. 458-462. 1981.
- R.J. Maguire
- "Pathways and Fates of Toxic Substances in Aquatic Environments." Canada Water Year Book 1979-80 (Water Research Edition). pp. 43-46. 1981.
- R.J. Maguire  
E.J. Hale
- "Surface Water Microlayers as Reservoirs of Environmental Contaminants." NWRI Report. October 1981.
- R.J. Maguire  
E.J. Hale
- "Butyltins in the Great Lakes Basin." NWRI Report. December 1981.
- R.J. Maguire  
Y.K. Chau  
G.A. Bengert  
E.J. Hale  
P.T.S. Wong  
O. Kramar
- "Occurrence of Organotin Compounds in Ontario Lakes." (Submitted for publication.)
- A. Mudroch
- "Major Elements and Metals Concentration in Sediment Profiles at the Niagara River Mouth Area." Abstract, XXV Conf. IAGLR, Sault Ste. Marie, Ontario. 1982.
- A. Mudroch  
M. Munawar
- "The Effects of Sediment Elutriates on Primary Production." Water Resources Research. (Submitted for publication.) 1982a.
- A. Mudroch  
M. Munawar
- "Little Current - Specific Case for Bioassays." Unpublished Report. 1982b.
- A. Mudroch  
M. Munawar
- "Characterization of Suspended Solids from Lake Erie." Hydrobiologia. (Submitted for publication.) 1982c.
- M. Munawar  
A. Mudroch
- "Phytoplankton Bioassays Using Sediment of the Niagara River Mouth." Abstract, XXV Conf. IAGLR, Sault Ste. Marie, Ontario. 1982.

- M. Munawar  
A. Mudroch  
R.L. Thomas "In Search of a Sensitive Bioassay Technique for the Assessment of Effects of Dredge Spoil Disposal." Water Pollution Res. J. Can. (Submitted.) 1982.
- F.I. Onuska  
A. Mudroch  
K. Terry "GS/MS Analysis of Organic Contaminants in Lake Ontario Sediment." Abstract, XXV Conf. IAGLR, Sault Ste. Marie, Ontario. 1982.
- R.G. Sandilands  
A. Mudroch "The Nepheloid Layer in Lake Ontario." Abstract, XXV Conf. IAGLR, Sault Ste. Marie, Ontario. 1982.
- E. Nagy  
B.F. Scott  
J. Hart "The Fate of Oil and Dispersant Mixtures in Freshwater Ecosystems." EPS Report No. EPS 4-EC-81-3. 1982.
- B.G. Oliver "Dihaloacetonitriles in Drinking Water: Algae and Fulvic Acid as Precursors." Environ. Sci. Technol. (Submitted.)
- B.G. Oliver  
K.D. Bothen "Chlorobenzenes in Sediments, Water and Selected Fish from Lakes Superior, Huron, Erie, and Ontario." Environ. Sci. Technol. (In press.)
- B.G. Oliver  
K.D. Bothen "Extraction and Cleanup Procedures for Measuring Chlorobenzenes in Sediments and Fish by Capillary Gas Chromatography." Int. J. Environ. Anal. Chem. (In press.)
- B.G. Oliver  
E.M. Thurman "The Influence of Aquatic Humic Substance Properties on Trihalomethane Potential." In Water Chlorination: Environmental Impact and Health Effects, Vol. 3. (In press.)
- B.G. Oliver  
G. Slawych "The Organic Contribution to the Acidity of Natural Waters." Environ. Sci. and Technol. (Submitted.)
- R.F. Platford  
J.H. Carey  
E.J. Hale "The Environmental Significance of Surface Films. I. Octanol-Water Partition Coefficients for DDT and Hexachlorobenzene." Environmental Pollution B. (In press.)
- R.F. Platford "The Environmental Significance of Surface Films. II. Enhanced Partitioning of Lindane in Thin Films of Octanol on the Surface of Water." Chemosphere, 10, pp. 719-722. 1981.
- R.F. Platford "Pesticide Partitioning in Artificial Surface Films." Presented at 24th Conference on Great Lakes Research, Columbus, Ohio, April 28-30, 1981.

R.F. Platford "Pesticide Partitioning in Artificial Surface Films". Journal of Great Lakes Research. (Submitted.) 1981.

B.F. Scott "Impact of Oil and Oil-Dispersant Mixtures on  
B.J. Dutka Freshwater Pond Ecosystems." NWRI Report. October  
J.P. Sherry 1981.  
V. Glooschenko

P.J. Wade  
W.D. Taylor  
E. Nagy  
N.B. Snow  
D.B. Carlisle

B.F. Scott "Fate and Effect of 2,4-D Formulations as Herbicides  
D.S. Painter in Aquatic Ecosystems. Part 1." NWRI Report. May,  
E. Nagy 1981.  
B.J. Dutka

W.D. Taylor

B.F. Scott "Fate and Effect of 2,4-D as Herbicides in Aquatic  
D.S. Painter Ecosystems." In Proc. of 16th Annual Workshop for  
E. Nagy Pest. Res. and 9th Annual Workshop on the Chem. and  
B.J. Dutka Biochem. of Herb., Winnipeg. 1981.

B.F. Scott "Simultaneous Determination of 2,4-D and 2,4-DCP in  
E. Nagy Water and Sediment Samples." (Submitted.) Ind.  
J. Hart Research and Dev. (Also presented at Labcon, Sept.  
B.K. Afghan 1981, Chicago). 1981.

#### **Analytical Methods Division**

B.K. Afghan "Biomass Estimation by Measurement of Adenosine  
Triphosphate (ATP)." International Biological  
Program (IBP) Handbook No. 12. 1981.

B.K. Afghan "Concentration of Polynuclear Aromatic Hydrocarbons  
R.J. Wilkinson in Natural Waters Using Open Cell Polyurethane  
A. Chow Foams." (Submitted.) 1981. Water Research.  
T.W. Findley  
H.D. Gessor,  
U. of Manitoba  
K.I. Srikaneswaran,  
U. of Brandon

B.F. Scott "Simultaneous Determination of 2,4-D and  
E. Nagy 2,4-Di-chlorophenol from Water and a Clay Sediment."  
J. Hart Industrial R&D. (Also presented at LABCON-81 in  
B.K. Afghan Chicago.) (Submitted.) 1981.

- B.K. Afghan  
J. Lawrence "Clean and Hazardous Chemicals Laboratory at National Water Research Institute, Canada Centre for Inland Waters." Canadian Research, November (December, 1981).
- B.K. Afghan  
J.F. Ryan "Method for Determination of Carbamate Pesticides in Environmental Samples (HPLC-Multidetector System)." 1981.
- J.W. ApSimon  
Kazu Yamasaki  
A. Fruchier  
A.S.Y. Chau "Carbon-carbon bond cleavage in an epoxide. 2,3,4,5,6-Hexachloro-12-oxaphentacyclo-[5.4.1.1.8,11<sup>0</sup>3,10<sup>0</sup>5,9] tridecane; A minor, product from the acid treatment of endrin <sup>1.5</sup>." Can. J. Chem., 60. 1982.
- B.K. Afghan  
A.W. Wolkoff "High Performance Liquid Chromatography in Environmental Analysis - Present and Future Applications." J. of Liq. Chrom. 4, pp. 99-139. 1981.
- G.E. Batley  
B.K. Afghan "Voltammetric Analysis of Some Carbamate Pesticides." J. of Electroanal. Chem. 125, pp. 437-445. 1981.
- B.K. Afghan "Test Method for Adenosine Triphosphate (ATP) Content of Microorganisms in Water." Annual Book of ASTM Standards, Part 31, 1981, D4012-2.
- B.K. Afghan  
(Coordinator) "Water Quality - Chapter 3. Canada Water Year Book 1979-80, Water Research Edition." Environment Canada, pp. 55-69. 1981.
- A.S.Y. Chau "The Role of Standard Reference Materials in Analytical Quality Assurance for Environmental Studies." Submitted to WHO Bulletin. 1981.
- J.W. ApSimon  
A.S.Y. Chau  
Robin Sampson  
H. Tze  
A. Fruchier "The Reaction of Heptachlor on Alumina Impregnated with H<sub>2</sub>SO<sub>4</sub> in the Presence of Various Aromatic Compounds." Canadian J. of Chemistry. 1981.
- B.J. Dutka  
A. Jova  
J. Brechin "Evaluation of Four Concentration/Extraction Procedures on Waters and Effluents Collected for use with the Salmonella typhimurium Screening Procedure for Mutagens." Bull. Environm. Contam. Toxicol: 27, pp. 758-764. 1981.
- B.J. Dutka  
K.K. Kwan "Comparison of Three Microbial Toxicity Screening Tests with the Microtox Test." Bull. Environm. Contam. Toxicol. 27:753-757. 1981.



- B.J. Dutka  
A. Jova "Evaluation of Four Concentration/Extraction Procedures on Waters and Effluents Collected from the Lower Great Lakes Basin for Use with the Salmonella typhimurium Screening Procedure for Mutagens." CCIW-IWD Report Series. Bull Environm. Contam. Toxicol. 27:758-764. 1981.
- B.F. Scott  
B.J. Dutka  
J.P. Sherry  
W. Glooschenko  
P.J. Wade  
W.D. Taylor  
E. Nagy  
N.B. Snow  
D.B. Carlisle "Impact of Oil and Oil-Dispersant Mixtures on Freshwater Pond Ecosystems." IWD Scientific Series 130. 1981.
- P.D. Goulden  
D.H.J. Anthony "Determination of Trace Metals in Fresh Waters by Inductively Coupled Argon Plasma Atomic Emission Spectrometry Using a Heated Spray Chamber and Desolution." Analytical Chemistry. 54. 1678-81. 1981.
- J. Lawrence "An Overview of Environmental Trace Analysis." Published as Taped Proceedings of Session 9, LABCON 81 - Chicago, September 15-17, 1981.
- F.I. Onuska  
A.G. Harrison  
C.W. Tsang "Chemical Ionization Mass Spectrometry of Specific Polychlorinated Biphenyl Isomers." Anal. Chem., 53, pp. 1183-1186. 1981.
- F.I. Onuska "Selectivity and Sensitivity of Electron Capture Detector for Determination of Dioxins." Published as taped Proceedings of Session 9A by Professional Cassette Centre, Pasadena, CA; LABCON 81, Chicago, Ill. 1981.
- B.J. Dutka "Pseudomonas aeruginosa, A Controversial Indicator-Pathogen in Membrane Filtration, Application, Techniques and Problems." ed. B.J. Dutka. Marcel Dekker Inc. New York and Basel. pp 119-128. 1981.
- A.H. El-Shaarawi  
S.R. Esterby  
B.J. Dutka "Bacterial Density in Water Determined by Poisson or Negative Binomial Distributions." Applied and Environ. Microbiol. 41:107-116. 1981.
- F.I. Onuska  
M.E. Comba  
J.A. Coburn "Exchange of Comments on the Determination of Mirex and Its Degradation Products by Capillary GC/MS." Anal. Chem. (Submitted.) 1981.

- S.S. Rao  
A.A. Jurkovic  
B.J. Dutka      "Some factors Influencing the Enumeration of Metabolizing Aquatic Bacteria." Journal of Environmental Measurement and Application. (In press.)
- S.S. Rao  
M.N. Charlton      "Oxygen Depletion in Central and Eastern Lake Erie: Relationship with Bacteria, Particulate Organic Carbon and Morphometry." Journal of Great Lakes Research. 1981.
- S.S. Rao      "Microbiological Studies of the Kejimikujic Watershed." For publication in the Proc. of the Workshop on Kejimikujic Lake Basin Study. 1981.
- I. Sekerka  
J.F. Lechner      "Potentionmetric Determination of Organohalides in Water." Accepted. Jour. of Environmental Analytical Chemistry. 1981.
- I. Sekerka  
J.F. Lechner      "Reference Electrode Based on Perfluorosulfonic Acid Membranes." Accepted. Analytical Letters. 1981.
- J.W. ApSimon  
A.S.Y. Chau  
A. Fruchier      "The Reaction of Heptachlor on Alumina Impregnated with Sulfuric Acid. A Ready Synthesis of 3-Exophenylchlordene." Tetrachedron Letters. (Submitted.) 1981.
- S.S. Rao  
A.A. Jurkovic  
B.J. Dutka      "Application of the Acridine Orange Inter-formazan Reduction Technique to Estimate Fresh Water Bacterial Activity." Eau du Québec. Vol. 14, No. 3, p. 234. 1981.
- B.J. Dutka  
K.K. Kwan      "Toxicity Testing of Industrial Effluents by Rainbow Trout, Sprillum voltans and Microtox Testing System." Eau du Québec, Vol. 14, No. 3, p. 230. 1981.
- B.K. Afghan      "Progrès dans la chromatographie liquide haute pression et ses applications à l'analyse d'échantillons environnementaux." Eau du Québec, Vol. 14, No. 3, p. 204. 1981.
- P.D. Goulden  
D.H.J. Anthony  
K.D. Austen      "Determination of Arsenic and Selenium in Water, Fish and Sediments by Inductively Coupled Argon Plasma Emission Spectrometry." Anal. Chem. 53:2027-29. 1981.
- I. Sekerka  
J.F. Lechner      "High Speed Dissolved Oxygen, Conductance and Temperature Measurement by Alternating Standard Sample Technique." Euroanalysis-IV Proceedings, AMD, NWRI, Burlington.

## INTERNAL REPORTS

- |  |  |
|--|--|
| B.K. Afghan<br>R.J. Wilkinson                                      | "Method for Determination of Polynuclear Aromatic Hydro-carbons in Environmental Samples (HPLC-Multidetecation System)." AMD - An internal Report. 1981.               |
| B.K. Afghan<br>J.F. Ryan   | "Method for Determination of Carbamate Pesticides in Environmental Samples." AMD - An internal report. 1981.   |
| V. Cheam<br>A.S.Y. Chau  | "Final Summary Report - National Interlaboratory Quality Control Studies Nos. 29 and 30 - Major Ions in Water." Unpublished Report to All Participants of N.Q.C. 1981. |
| B.J. Dutka<br>J. Brechin   | "Study of Mutagenic and Toxic Activity in Waters and Sewage Effluent within the Great Lakes Basin." NWRI Manuscript. 1981.   |
| B.J. Dutka<br>K.K. Kwan  | "Comparison of the Sensitivity of Four Microbiological Procedures Used in Toxicity Screening Tests." Unpublished Report. 1981.   |
| B.J. Dutka<br>K.K. Kwan  | "Comparison of Four Bacterial Toxicity Screening Procedures on Mixtures of Chemicals." Unpublished Report.   |
| B.F. Scott<br>D.S. Painter<br>E. Nagy<br>B.J. Dutka<br>W.D. Taylor | "Fate and Effects of 2,4-D Formulations as Herbicides in Aquatic Ecosystems, Part I." Unpublished Report. 1981.  |
| B.J. Dutka<br>E. Lew   | "Cultivation of Cyanide Degrading Bacteria from Tailing Ponds." NWRI Report Series. 1981.  |
| F.I. Onuska<br>R. Thomson<br>K. Terry                              | "A Comparison of Methodology for the Determination of Chlorobenzenes in Sediment Samples." 1981.   |
| S.S. Rao<br>A.A. Jurkovic<br>P. Robson                             | "Effects of Acid Precipitation on Microbial Populations in Northern Ontario Lakes." Unpublished Report. 1981.  |
| L.S. Grey<br>S.S. Rao<br>D.J. McQueen                              | "Observations of Bacteriological Conditions in a Small Eutrophic Kettle Lake." Unpublished Report. 1981.   |

K.I. Aspila	"Interlaboratory Study No. 28 - Arsenic and Selenium in Sediments and Soils." Final Summary Report June 22, 1981. NWRI Report Series. 1981.
A.S.Y. Chau	"An Overview of an Effective Quality Assurance Program: Field and Laboratory." To be published in the IWD Report Series. Presented at the Field Q.C. Workshop November 19-20, 1981.
A.S.Y. Chau B. Lee	"How Reliable are the PCBs Data?" Outside Journal - In the Proceedings of the 16th Annual Western Pesticide Workshop. Oral Presentation. 1981.
V. Cheam	"Special Interlaboratory Quality Control Study: Evaluation of Total Alkalinity Methods of Fixed-End Point Titration, IR/CO <sub>2</sub> Evolution, Alkalinity/Acidity in Precipitation Samples, and Gran Analysis - IROC 74 A." IWD-HQ - Water Quality Branch Regional Managers. 1981.
V. Cheam	"Summary Report on IRQC Studies No. 76-77 Trace Metals, Major Ions and Physical Parameters." Interregional Q.C. Report - Confidential. 1981.
V. Cheam	"Summary Report on IRQC Studies No. 78-79 - Major Cations, Arsenic, Selenium and Total PCBs." Interregional Q.C. Report. 1981.
V. Cheam	"IRQC Studies No. 74-75." 1981.
V. Cheam A.S.Y. Chau	"Specification Studies and Statements. I. Trace Metals, Major Ions, Nutrients, Physical Parameters and Miscellaneous Inorganic Parameters in Water at Three Concentration Levels." Unpublished Report. 1981.
V. Cheam	"Summary Report - IRQC Studies No. 80-81 Extractable Trace Metals Methods by Direct Aspiration Technique." Interregional Q.C. Report. 1981.
H.B. Lee A.S.Y. Chau	"Development, Preparation and Application of the First Standard Reference Materials (SRM's) for PCB's Analysis in Sediment (ABSTRACT)." Presented by H.B. Lee at the 7th Annual Meeting of FACSS. 1981.
H.B. Lee A.S.Y. Chau	"National Interlaboratory Quality Control Study No. 27: PCBs in Naturally Contaminated Dry Sediments." NWRI Report Series. 1981.



H.B. Lee A.S.Y. Chau	"National Interlaboratory Quality Control Study No. 25: PCBs in Wet Sediments." NWRI Report Series. 1981.
H.C. Pulley	"Annual Report." Computer Services Section Support Fiscal Year 1980-81. 1981.
H.C. Pulley	"Annual EDP Report and Plan 1981-82". Government Report. 1981.
F.I. Onuska	"Determination of Chlorinated Benzenes in Sediments. Steam Distillation Method." 1981.
F.I. Onuska R. Thomson	"Canagagigue Creek - Acid Extract Sample Report." 1981.
F.I. Onuska	"Treatise on Selected Ion Monitoring Using SS-200 Data System." 1981.

#### **Aquatic Physics & Systems Division**

A.G. Bobba R.P. Bukata	"Parameterization of Contaminant Transport Through an Anisotropic Unconfined Aquifer." Nordic Hydrology, Vol. 11, pp. 187-208. 1980.
F.M. Boyce D.C. Lam	"The Physical Limnology of the North American Great Lakes." Verh. Internat. Verein. Limnol., Vol. 21, pp. 1650-1665. 1981.
B. Bordner R.R. Christian A. El-Shaarawi H. Kenney E. Means R. Moser H. Victoreen W.O. Pipes	"Issues Paper on Monitoring." Workshop on Microbiological Contaminants in Drinking Water. EPA Report, 56 pp. 1981.
R.P. Bukata J.H. Jerome J.E. Bruton S.C. Jain H.H. Zwick	"An Optical Water Quality Model of Lake Ontario. Part I. Determination of the Optical Cross-sections of Organic and Inorganic Particulates in Lake Ontario." Applied Optics, Vol. 20, pp. 1696-1703. 1981.
R.P. Bukata J.E. Bruton J.H. Jerome S.C. Jain H.H. Zwick	"An Optical Water Quality Model of Lake Ontario. Part II. Determination of Chlorophyll <u>a</u> and Suspended Mineral Concentrations of Natural Waters from Submersible and Low Altitude Optical Sensors." Applied Optics, Vol. 20, pp. 1704-1714. 1981.

- R.P. Bukata      "Validation of a Five-component Optical Model for  
J.H. Jerome      Estimating Chlorophyll a and Suspended Mineral  
J.E. Bruton      Concentrations in Lake Ontario." Applied Optics,  
Vol. 20, pp. 3472-3477. 1981.
- A. El-Shaarawi "On Determining the Number of Samples Required to  
Estimate the Phosphorus Input Contributed by Niagara  
River to Lake Ontario." Proc. 4th Int. Time Series  
Meeting, Valencia, Spain, June 22-26, 1981. (In press.)  
1981.
- A. El-Shaarawi "Enumeration and Statistical Inference." In: Bacterial  
W.O. Pipes      Indicators of Pollution (CRC publication) pp. 43-66.  
1981.
- A. El-Shaarawi "Time Series Methods in Hydrosiences." Proceedings of  
an International Conference held at Canada Centre for  
Inland Waters, 1981. Elsevier Scientific Publishing  
Compay, 614 pp. (In press.) 1981.
- A. El-Shaarawi "Inference about the point of Change in a Regression  
S.R. Esterby      Model with a Stationary Error Process." In: Time Series  
Methods in Hydrosiences. (A. El-Shaarawi, Ed.)  
Elsevier, pp. 55-67. (In press.) 1981.
- A. El-Shaarawi "The Change Point Problem for a Sequence of Binomial  
L.D. Delorme      Random Variables." In: Time Series Methods in  
Hydrosiences. (A. El-Shaarawi, Ed.) Elsevier. (In  
press.) 1981.
- A.S. Fraser      "Loading Estimates to Lake Erie, 1967-1976." IWD  
K.E. Willson      Scientific Series No. 120, 23 pp. 1981.
- E. Halfon      "The Current Status and Future of Systems Ecology: A  
Personal View." INTECOL Bulletin, Vols. 7/8, pp. 30-32.  
1980.
- E. Halfon      "Distribution et transformation du fenitrothion épandu  
J. Maguire      sur un étang: modélisation dans des conditions  
d'incertitude." Eau de Québec, Vol. 14, pp. 216-220.  
1981.
- E. Halfon      "Uncertainty in Modelling the Environmental Fate of Mirex  
in Lake Ontario." In: A General Survey of Systems  
Methodology. (V. Troncale Ed.) Proc. 26th Annual Meeting  
of the Society for General Systems Research, Washington,  
D.C., Jan. 5-9, pp. 553-558. 1982.

- P.F. Hamblin      "An Evaluation of an Unattended Current and Temperature  
R. Kuehnelt      Profiler for Deep Lakes." *Limnology and Oceanography*,  
Vol. 25, No. 6, pp. 1128-1141. 1980.
- P.F. Hamblin      "An Analysis of Advective Diffusion in Branching  
Channels." *J. Fluid Mech.*, Vol. 99, pp. 101-110. 1980.
- P.F. Hamblin      "A Model of the Mean Field Distribution of a Dissolved  
E.C. Carmack      Substance within the Riverine Layer of a Fjord lake."  
*Water Resources Res.*, Vol. 16, pp. 1094-1098. 1980.
- P.F. Hamblin      "Mean Field Distributions of a Dissolved Substance in the  
E.C. Carmack      Vicinity of Branches in a Fjord System, 1980." *In: Fjord  
Oceanography.* (H.J. Freeland, Ed.) Plenum Press, pp.  
377-398. 1980.
- P.F. Hamblin      "On Length Scales Associated with Rotating Intrusive  
J. Imberger      Flow." *Ocean Modelling*, Vol. 40, pp. 10-11. 1981.
- P.F. Hamblin      Review of "Waves in the Ocean." (P.H. LeBlond and  
L.A. Mysak). *Atmosphere-Ocean*, Vol. 19, p. 73. 1981.
- J. Imberger      "Dynamics of Lakes, Reservoirs, and Cooling Ponds."  
P.F. Hamblin      *Ann. Rev. Fluid Mech.*, Vol. 14, pp. 153-187. 1982.
- J.H. Jerome      "Influence of Scattering Phenomena on the Solar Zenith  
J.E. Bruton      Angle Dependence of In-water Irradiance Levels." *Applied  
R.P. Bukata      Optics*, Vol. 21, pp. 642-647. 1982.
- D.C.L. Lam      "An Inverse Problem Approach to Modelling Coastal  
C.R. Murthy      Effluent Plumes." *J. Advances in Water Resources*,  
K.C. Miners      Vol. 4, pp. 185-190. 1981.
- D.C.L. Lam      "Finite Element Analysis of Horizontal and Vertical  
Turbulent Diffusion Problems in Lakes." *J. Advances in  
Water Resources*, Vol. 4. (In press.) 1982.
- D.C.L. Lam      "Mass Balance Models of Phosphorus in Sediments and  
W.M. Schertzer      Water." *Hydrobiologia*, Vol. 92. (In press.) 1982.  
A.S. Fraser
- D.C.L. Lam      "Water Quality and Pollutant Transport Models for  
T.J. Simons      Canadian Aquatic Regimes: A State-of-the-art Review."  
*Proc. UNESCO International Workshop on the Comparison of  
Application of Mathematical Models for the Assessment of  
Changes in Water Quality in River Basins both Surface  
Water and Groundwater, La Coruna, Spain, April, 1982,  
(UNESCO-IHP, publ., Paris), 23 pp. (In press.), 1982.*

- C.R. Murthy      "Variability of Currents and Horizontal Turbulent  
N.N. Filatov      Exchange Coefficients in Lakes Ladoga, Huron and  
Ontario."      Journal of Oceanology, USSR Academy of  
Sciences, Vol. 21, No. 3, pp. 447-451. 1981.
- C.R. Murthy      "Structure of the Flow within the Coastal Boundary Layer  
D.S. Dunbar      of the Great Lakes."      Journal of Physical Oceanography,  
Vol. 11, No. 11, pp. 1567-1577. 1981.
- H. Tamura      "Identification of a Dynamic Lake Model by the Group  
E. Halfon      Method of Data Handling: An Application to Lake  
Ontario."      Ecological Modelling, Vol. 11, pp. 81-100.  
1980.
- M.E. Thompson      "Variations in the Degree of Acidification of River  
E.B. Bennett      Waters Observed in Atlantic Canada."      Proc. EPA/OECD  
Int. Symp. on Inland Waters and Lake Restoration,  
Portland, Maine, Sept., 1980.
- M.E. Thompson      "Exchange of Marine Sodium for Calcium During Chemical  
Weathering in the Isle aux Morts River Basin,  
Newfoundland."      Geoch. Cosmoch. Acta, Vol. 46,  
pp. 361-365. 1982.
- M.E. Thompson      "The Cation Denudation Rate as a Quantitative Index of  
Sensitivity of Eastern Canadian Rivers to Acidic  
Atmospheric Precipitation."      Water, Air and Soil  
Pollution, Special issue. (In press.) 1982.
- H.H. Zwick      "A Satellite/airborne and in situ Water Quality  
S.C. Jain      Experiment in Lake Ontario."      In: Proceedings of the  
R.P. Bukata      ISPra Workshop on the EURASEP Ocean Color Scanner  
Experiments, pp. 181-198. 1980.

#### CONTRIBUTIONS

- M.E. Thompson      USA-Canada Memorandum of Intent on Transboundary Air  
Pollution. Interim Report, October, 1981.
- M.E. Thompson      Acidification in the Canadian Aquatic Environment  
(H.H. Harvey et al., Eds.) NRCC No. 18475. 1981.

#### UNPUBLISHED AND DRAFT REPORTS

- F.M. Boyce      "Resume of Lake Erie Workshop - September 17-18, 1981."  
Unpublished Report. 66 pp. 1981.
- F.M. Boyce      "Summer Availability of Cold Lake Water off Toronto:  
D.G. Robertson      Project FREECOOL." Unpublished Report, 89 pp. 1981.



- F. Chiocchio "Lake Erie Hypolimnion and Mesolimnion Flow Exchange between Central and Eastern Basin during 1978." Unpublished Report No. APSD009. 94 pp. 1981.
- F. Chiocchio "Geodyne (920-3) Current Meter Direction Investigation." Unpublished Report No. APSD-82-007. 34 pp. 1982.
- A.S. Fraser "Salt in the Great Lakes." Unpublished Report. 22 pp. 1981.
- R.O.W. Kuehnel "A Coastal Dispersion Model for Effluent Plumes." Unpublished Report. 128 pp. 1981.
- C.R. Murthy
- K.C. Miners
- B. Kohli
- Y. Hamdy
- D.C.L. Lam "Simulation of Lake Erie Water Quality Responses to W.M. Schertzer Loading and Weather Variations." Unpublished Report. 420 pp. 1982.
- A.S. Fraser
- A.J. Niimi "An Evaluation of the Effects of Enhanced Thermal Loading in Port Hope Harbour, Lake Ontario." March, 1982.
- P.F. Hamblin
- T.J. Simons "The Seasonal Climate of the Upper Ocean: Data Analysis and Model Development." Unpublished Report. 67 pp. 1981.
- M.E. Thompson "Selected Canadian lakes - Cations, Sulfate, pH,  $P_{CO_2}$  Relationships." Unpublished Report. 48 pp. 1981.
- M.B. Hutton
- M.E. Thompson "Acidification of Algonquin Lakes." Unpublished Report. 1982.
- G. Beggs
- F.J. Hicks
- M.E. Thompson "Sulfate in Lakes of Eastern Canada: Calculated loads Compared with Measured Wet Deposition." Unpublished Report. 24 pp. Appendix, 35 pp. 1982.
- M.B. Hutton
- M.E. Thompson "Long-range Transport of Airborne Pollutants: Surface Water Monitoring Program." Unpublished Report. 12 pp. 1982.
- M.E. Thompson "Seasalt Correction Factors - A Critical Analysis of the CANSAP Major Ion Data for Sable Island, Nova Scotia." Draft Report. 1982.

## Aquatic Ecology Division

- N.M. Arafat                    "Method for the Simultaneous Determination of Arsenic,  
W.A. Glooschenko           Aluminum, Iron, Zinc, Chromium and Copper in Plant  
Tissue Without the Use of Perchloric Acid." In: The  
Analyst, 106:1174-1178, 1981.
- N.M. Arafat                    "The Use of Bog Vegetation as an Indicator of  
W.A. Glooschenko           Atmospheric Deposition of Arsenic in Northern  
Ontario." NWRI Report Series, 1981. Env. Pollut.  
(In press.)
- J. Barica                      "Hypereutrophy - The Ultimate Stage of  
Eutrophication." Water Qual. Bull., 6(4):95-98, 155.  
1981.
- P.A. Meyers                    "Changes in Spruce Composition Following Burial in  
M.J. Leenhere               Lake Sediments for 10,000 years." Nature,  
K.M. Erstfeld               287(5782):534-536. 1980.  
R.A. Bourbonniere
- D.K. Rae                      "Southern Lake Michigan Sediments: Changes in  
R.A. Bourbonniere           Accumulation Rate, Mineralogy, and Organic Content."  
P.A. Meyers               J. Great Lakes Res., 6(4):321-330. 1980.
- P.A. Meyers                    "Hydrocarbons and Fatty Acids in Two Cores of Lake  
R.A. Bourbonniere           Huron Sediments." Geochimica et Cosmochimica Acta,  
N. Takeuchi               44:1215-1221. 1980.
- R.A. Bourbonniere              "The Great Lakes Sediment Bank." Abstract presented  
W.M.J. Strachan           at IAGLR., Columbus, Ohio, April 28-30. 1981.  
T. Mayer
- R.A. Bourbonniere              "Geolipids in Canadian Shield Lake Sediments."  
T. Mayer                    Abstract presented at the ASLO Meeting, Milwaukee,  
Wisconsin, June 15-18, 1981.
- B.G. Brownlee                "A Review of Benzothiazoles in the Aquatic  
J.H. Carey                  Environment." IWD Scientific Series No. 126. 1982.
- B.K. Burnison                "Colloidal Polysaccharides Found in the Dissolved  
G.G. Leppard               Organic Carbon Fraction of a Lake." Proc. 2nd  
Internat. Symp. Microbial Ecology, Univ. of Warwick.  
September, 1980.
- B.K. Burnison                "Physical Separation of 'Dissolved' Organic Carbon  
G.G. Leppard               Fractions from Lake Water." Abstract published in  
Proc. of 44th Annual Amer. Soc. Limnol. & Ocean.  
1981.
- R. Carignan                  "Postdepositional Mobility of Phosphorus in Lake  
R.J. Flett                  Sediments." Limnol. Oceanogr., 26(2):361-366. 1981.

- R. Carignan "An Empirical Model to Estimate the Relative Importance of Roots in Phosphorus Uptake by Aquatic Macrophytes." Can. J. Fish. Aquat. Sci., 39:243-247. 1982.
- R. Carignan "Phosphorus Release by Aquatic Macrophytes: Significance to Epiphyton and Phytoplankton." J. Kalff Limnol. Oceanogr. (In press.) 1982.
- M.N. Charlton "Primary Production and Respiration in Central and Eastern Lake Erie." Abstract presented at IAGLR, Columbus, Ohio. 1981.  
D.R.S. Lean  
A.P. Abbott  
W. Booth
- H.F.H. Dobson "The Lake Ontario Phosphorus Story: How the Lake Is Doing up to Now." Abstract presented at the Hamilton Environmental Conference, November, 1980.
- H.F.H. Dobson "Quantification of the Lake Trophic Typologies of Naumann (Surface Quality) and Thienemann (Oxygen) with Special Reference to the Great Lakes." J. Great Lakes Res., 7(2):182-193. 1981.  
S.C. Chapra
- H.F.H. Dobson "Trophic Conditions and Trends in the Laurentian Great Lakes." WHO Water Quality Bulletin, 6(4):146-151, 158 and 160. In French: "Conditions et tendances trophiques dans les Grands lacs laurentiens." OMS Bulletin de la qualité des eaux, 6(4):141-146. 1981.
- S.R. Esterby "Examples of Inference about a Point of Change." A.H. El-Shaarawi Unpublished Report. 1980.
- S.R. Esterby "Procedures for Grouping Counts into Homogeneous Sets." Abstract presented at American Statistical Association Meeting, Houston, Texas. August, 1980.
- S.R. Esterby "Summary of the Bacterial Density in Water Using the Poisson or Negative Binomial Distributions." Applied A.H. El-Shaarawi and Environmental Microbiology, Vol. 41, pp. 107-116. B.J. Dutka 1981.
- S.R. Esterby "Characterization of Spatial and Temporal Variability of Water Quality Parameters." Summaries of Conference A.H. El-Shaarawi Presentations, Environmetrics 81, Alexandria, Virginia, pp. 156-157. 1981.
- S.R. Esterby "Inference about the Point of Change in a Regression A.H. El-Shaarawi Model." Applied Statistics, Vol. 30, pp. 277-285. 1981.

- S.R. Esterby            "Likelihood Inference about the Point of Change in a  
A.H. El-Shaarawi       Regression Regime."    Journal of Hydrology, Vol. 53,  
pp. 17-30.    1981.
- S.R. Esterby            "Regression Analysis of the Spatial Variation of a  
A.H. El-Shaarawi       Limnological Characteristic."    Eau du Quebec, Vol. 14,  
pp. 222-228.    1981.
- W.A. Glooschenko       "Geochemical Distribution of Trace Metals and  
J. Capobianco           Organochlorine Contaminants of a Lake Ontario  
J. Coburn               Shoreline Marsh."    Water, Air & Soil Pollution,  
V. Glooschenko       15(2):197-213.    1981.
- W.A. Glooschenko       "Trace Element Content of Northern Ontario Peat."  
J. Capobianco           Env. Sci. Technol. (In press.)    1981.
- K.E. Clarke            "Sedimentary Characteristics of the Coastal  
J.P. Martini            Environment of North Point, James Bay, Ontario."  
W.A. Glooschenko       Nat. Can. (In press.)    1982.
- W.A. Glooschenko       "Seasonal Changes in Soil Salinity in a Subarctic Salt  
K.E. Clarke            Marsh."    Nat. Can. (In press.)    1981.
- W.A. Glooschenko       "Net Aerial Primary Production of a James Bay,  
N.S. Harper            Ontario, Salt Marsh."    Can. J. Bot. (In press.)  
1981.
- W.A. Glooschenko       "Salt Marshes of Canada."    Proc. Int. Wetlands Conf.,  
New Delhi, India. (In press.)    1981.
- W.A. Glooschenko       "Salt Marshes of the Ontario Coast of Hudson Bay,  
I.P. Martini            Canada."    Proc. 2nd Ann. Soc. Wetland Sci. Conf.,  
Louisiana, May, 1981. (In press.)
- L. Kalas                "Climatic Oscillations and Their Impact on Taxonomic  
Diversity and Specimen Abundance Fluctuation of Late  
Quaternary Mollusca from the Pelee Shoal, Lake Erie,  
Canada."    Unpublished Report, 150 pp.    1981.
- L. Kalas                "Land Snails (Mollusca:Gastropoda) from Northern  
Alaska and Northwestern Canada."    Unpublished Report.  
312 pp.    1981.
- D.R.S. Lean            "Photosynthetic Response of Lake Plankton to Nutrient  
F.R. Pick               Enrichment: A Test for Nutrient Limitation."  
Limnol. Oceanogr., 26:1001-1017.    1981.
- R. Knowles            "Nitrous Oxide Concentrations in Lakes: Variations  
D.R.S. Lean            with Depth and Time."    Limnol. Oceanogr., 26:855-866.  
Y.K. Chau               1981.



- R. Knowles  
D.R.S. Lean  
Y.K. Chau "Patterns of Accumulation and Depletion of N<sub>2</sub> in Lakes." (Abstr.) Am. Soc. of Microbio., Dallas, March, 1981.
- W.D. Taylor  
D.R.S. Lean "Radiotracer Experiments on Phosphorus Uptake and Release by Limnetic Zooplankton." J. Fish. Aquatic. Sci., 38:1316-1321. 1981.
- D.R.S. Lean  
M.N. Charlton  
S.S. Rao  
A.P. Abbott "Photosynthesis by Different Size Groups of Phytoplankton Related to Phosphate Demand in Lake Erie." (Abstr.) IAGLR, Columbus, Ohio, April, 1981.
- D.R.S. Lean  
E. White "Chemical and Radiotracer Measurements of Phosphate Uptake by Lake Plankton." (Abstr.) III Annual Meeting of the Canadian Society of Theoretical and Applied Limnology (SIL), Montreal. 1981.
- D.R.S. Lean  
T.P. Murphy  
F.R. Pick "Photosynthetic Response of Lake Plankton to Combined Nutrient Enrichment." J. Phycol. (In press.)
- D.R.S. Lean  
E. White "Chemical and Radiotracer Measurements of Phosphorus Uptake by Lake Plankton." J. Fish Aquatic. Sci. (In press.)
- D.R.S. Lean "Partitioning of Phosphate Uptake by Different Size Classes of Lake Plankton: Implications for the Phosphate Radiobioassay." Limnol. Oceanogr. (In press.)
- G.G. Leppard  
B.K. Burnison "Colloidal Organic Fibrils of Polyanionic Nature are Abundant in Canadian Lakes." Abstr. 23rd Conf. Int. Assoc Great Lakes Res., p. 31. 1980.
- G.G. Leppard  
A. Massalski  
B.K. Burnison "Fibrillar Adhesives, Cell Surfaces and Pelagic Associations in the Water of Six Ontario lakes." Abstr. Proc. Can. Fed. Biol. Socs., 23, N 306. 1980.
- W.S. Fyfe  
B.I. Kronberg  
M. Peirce  
G.G. Leppard "Ferromanganese Nodules from Lake Ontario (Bay of Quinte): Minor Element Geochemistry." J. Great Lakes Res., 6:203-209. 1980.
- G.G. Leppard  
B.K. Burnison "An Emerging Interest in Colloidal Organic Fibrils." Chapter seven of the reference book "Trace Element Speciation in Surface Waters and Its Ecological Implications." Plenum Publishing Corp., New York, approx. 400 pp. 1982.

- G.G. Leppard "An Introduction to Trace Element Speciation in Surface Waters and its Ecological Implications." Chapter One of the reference book "Trace Element Speciation in Surface Waters and Its Ecological Implications." Plenum Publishing Corp., New York, approx. 400 pp. 1982.
- M.J. Tricker "57Fe Mössbauer Spectroscopic Studies of Electron-hopping Processes in Natural Crystals." J. Inorg. Nucl. Chem., 43:1169-1174. 1981.
- P.P. Vaishnava  
P.G. Manning "Observation of Electron-hopping in Vesuvianite by Mössbauer Spectroscopy." Phys. Stat. Solidi, 62:K89-93.
- P.P. Vaishnava  
M.J. Tricker  
P.G. Manning "Ferric Hydroxides in Surficial Sediments of the Great Lakes and Their Role in Phosphorus Availability: A Mössbauer Spectral Study." Can. Mineral., 19, pp. 525-530. 1981.
- P.G. Manning  
T. Birchall  
W. Jones "The Non-apatite Inorganic Phosphorus Binding Capacity of Ferric Hydroxides in Two Sediment Cores from Lakes Erie and Ontario: A Mössbauer Spectral Study." Can. Mineral. (In press.) 1982.
- T.P. Murphy  
B.G. Brownlee "Ammonia Volatilization in Hypertrophic Prairie Lakes." Can. J. Fish. Aquat. Sci., 38:1035-1039. 1981.
- T.P. Murphy  
B.G. Brownlee "Blue-green Algal Ammonia Uptake in Hypertrophic Prairie Lakes." Can. J. Fish. Aquat. Sci., 38:1040-1044. 1981.
- T.P. Murphy  
K.J. Hall  
I. Yesaki "Coprecipitation of Phosphate with Calcite in a Naturally Eutrophic Lake." Limnol. Oceanogr. (In press.) 1982.
- T.P. Murphy  
K.J. Hall  
I. Yesaki "Biogenic Regulation of Iron Availability in a Eutrophic Hardwater Lake." J. Total Sci. Environ. (In press.) 1982.
- J.O. Nriagu  
H.K.T. Wong  
R.D. Coker "Particulate and Dissolved Trace Metals in Lake Ontario." Water Research, 15:91-96. 1981.
- J.O. Nriagu "Acid Rain and the Chemistry of Trace Metals in Lakes Around Sudbury, Ontario." pp. 53-54 in Report of Workshop on Research Needs in Intermedia Transport, School of Engr. and Applied Sciences, Univ. of California, Los Angeles. 1981.

J.A. Nriagu H.K.T. Wong R.D. Cocker	"Deposition and Chemistry of Pollutant Metals in Lakes Around the Smelters at Sudbury, Ontario." Environ. Sci. Technol. (In press.)
D.S. Painter	"Documentation of Aquatic Macrophyte Distribution in the Grand River Watershed." Grand River Report #42, Ontario Ministry of the Environment. 1981.
D.S. Painter B.F. Scott E. Nagy W.D. Taylor	"Fate and Effects of 2,4-D Formulations as Herbicides in Aquatic Ecosystems. Part I." Environment Canada, NWRI, CCIW, Burlington, Ontario. 1981.
H.K.T. Wong J.O. Nriagu	"Heavy Metal Fluxes into Lakes Around Sudbury, Ontario." Abstract ASLO, Madison, Wisconsin, June 15-18, 1981.

#### Hydraulics Division

S. Beltaos	"Field Studies on the Response of Floating Ice Sheets to Moving Loads." Canadian Journal of Civil Engineering, Vol. 8, No. 1. 1981.
S. Beltaos	"Ice Freezeup and Breakup in Lower Thames River: 1979-80 Observations." Unpublished Report. December, 1981.
S. Beltaos	"River Ice Jams: Theory, Case Studies and Applications." Submitted to the Journal of the Hydraulics Division, ASCE. Unpublished Report. 1982.
S. Beltaos	"Initiation of River Ice Breakup." Submitted to Fourth Northern Research Basin Symposium Workshop to be held in March 1982, Norway. Unpublished Report. 1982.
P. Engel Y.L. Lau	"Hydraulic Model Study of Large Culvert Inlet Gratings." Unpublished Report. 1981.
P. Engel Y.L. Lau	"Bed-Load Discharge Coefficient." Unpublished Report. October, 1980. Journal of the Hydraulics Division, ASCE, Vol. 107, No. HY11. November, 1981.
P. Engel	"The Length of the Flow Separation Over Dunes." Unpublished Report, 1980. Journal of the Hydraulics Division, ASCE, Vol. 107, No. HY10. October, 1981.

P. Engel Y.L. Lau	"Discussion - Bar Resistance of Gravel-Bed Streams". Journal of the Hydraulics Division, ASCE, June, 1981.
P. Engel	"Discussion - Flow Resistance of Gravel Bed Streams". (Submitted.) ASCE, December, 1981.
B.G. Krishnappan	"Laboratory Verification of a Turbulent Flow Model." Submitted to the Journal of the Hydraulics Division, ASCE, 1981.
Y.L. Lau	"Velocity Distribution Under Floating Covers." Unpublished Report. August 1981. Canadian Journal of Civil Engineering, Vol. 9, No. 1, pp. 76-83. March, 1982.
Y.L. Lau	"Dispersion Coefficient for Natural Streams." Unpublished Report, October 1981; Submitted to Journal of Hydraulics Division, ASCE. 1981.
Y.L. Lau	"Suspended Sediment Effect on Flow Resistance." Unpublished Report, March 1982. Submitted to Journal of Hydraulics Division, ASCE. 1982.
J. Marsalek	"Study of Bridge Deck Drainage." A report to the Ministry of Transportation and Communications. Unpublished Report. April, 1981.
J. Marsalek	"Study of Road and Bridge Deck Drainage Systems." A report to the Ministry of Transportation and Communications. Unpublished Report. September, 1981.
J. Marsalek	"Calibration of the Tipping-Bucket Raingauge." Journal of Hydrology, Vol. 53, No. 10, pp. 343-354. October, 1981.
J. Marsalek D.G. Weatherbe G. Zukovs	"Research and Practice in Urban Runoff Control in Canada." Preprint No. 81-543, ASCE Annual Convention, St. Louis, Missouri, October 26-31, 1981.
J. Marsalek	"Adaptation of the ILLUDAS Model to a Desk-Top Computer." Technical Bulletin No. 120, NWRI/IWD, Burlington. 1981.
J. Marsalek	"(Collection of) Hydrological Data with Emphasis on Runoff." Unpublished Report. December, 1981.



- J. Marsalek "Administration and Organization of Data Collection Programs." Unpublished Report. December, 1981.
- J. Marsalek "Hydraulics of Open Channels, Conduits, and Subsurface Drainage." Unpublished Report. January, 1982.
- H.Y.F. Ng  
J. Marsalek "Vérification du modèle de gestion des eaux pluviales bassin versant expérimental de Malvern." Eau du Québec, Vol. 14, No. 3, pp. 237-241, août 1981.
- N.Y.F. Ng  
R. Boucher  
J. Dolanjski "Development of a Sequential Rain Sampler." Unpublished Report. 1981.
- G. Tsang "Fin Boom Ice Gate for Ice Control and Winter Navigation." Unpublished Report. May, 1981. International Symposium on Ice - Quebec, 1981.
- G. Tsang "Frazil and Anchor Ice - A Monograph." National Research Council. February, 1982.
- C.T. Bishop "Comparison of Simple Wave Prediction Models." Submitted to the ASCE Journal of the Waterway, Port, Coastal and Ocean Division. Unpublished Report. September, 1981. Revised May, 1982.
- C.T. Bishop  
B.A. Gallant "Construction of Goodyear Floating Tire Breakwater at La Salle Marina, Burlington, Ontario." Presented at the Second Conference on Floating Breakwaters held at Seattle, Washington, October 19-20, 1981.
- C.T. Bishop "Drag Tests on Pipe-Tire Floating Breakwater." Unpublished Report. 1981.
- V.W. Harms  
C.T. Bishop  
J.J. Westerink "Pipe-Tire Floating Breakwater Design Criteria." Presented at the Second Conference on Floating Breakwaters held at Seattle, Washington, October 19-20, 1981.
- C.T. Bishop  
V.W. Harms  
J.J. Westerink "Pipe-Tire Breakwater Model Tests - Data Report." Unpublished Report. March, 1982.
- M.A. Donelan  
W.J. Pierson "The Sampling Variability of Estimates of Spectra of Wind Generated Gravity Waves." Unpublished Report. May, 1981. Journal of Physical Oceanography. (Submitted.)

- M.A. Donelan "The Dependence of the Aerodynamic Drag Coefficient on Wave Parameters." Unpublished Report. December 1981. Extended Abstract, 1st International Conference on Meteorology and Air/Sea Interaction of the Coastal Zone.
- M.G. Skafel "Suspended Sediment in a Wave Field." Unpublished Report, April 1981. Atmosphere-Ocean Vol. 19, No. 3, pp. 274-278. 1981.
- B.G. Krishnappan
- M.G. Skafel "Suspended Sediment Distribution in a Wave Field." Unpublished Report. November, 1981. Journal of the Waterway, Port Coastal and Ocean Division, ASCE. (Submitted.)
- B.G. Krishnappan
- A.J. Zeman "Five-Year Investigation of Erosional Processes at a Study Site near Port Burwell, Ontario." Abstract, 24th Conference on Great Lakes Research. April, 1981.
- A.J. Zeman "Report to Public Works Canada on Borehole Stratigraphy, Particle Size and Clay Mineralogy, Port Burwell, Ontario." Unpublished Report. 1981.
- G. Tsang "Frazil and Anchor Ice in Rivers and Lakes - Chapter V. Hydraulics, Section V.2." River and Lake Ice Engineering, International Association for Hydraulics Research. March, 1982.
- J. Wong "Persistent Toxic Substances in Urban Runoff from the City of Cornwall." Unpublished Report. October, 1981.
- J. Wong "Persistent Toxic Substances in Urban Runoff." Proceedings Stormwater and Water Quality Management Modelling and SWMM Model Users Group Meeting, Niagara Falls, Ontario, September 28-29, 1981.
- J. Marsalek
- A.J. Zeman "Investigation of Erosional Processes at Port Burwell Study Site, Central Lake Erie. Part 1 - Historical Recession Rates and Recent Topographic Surveys." Unpublished Report. February, 1982. Restricted Distribution.
- M.R. Thompson
- G. Dolanjski "Handbook Notes for Acoustic Wave Height Sensor." March, 1981.
- G. Dolanjski "Handbook Notes for Portable Multiband Transmittance Profiler." Manual. May, 1981.

G. Dolanjski "Handbook Notes for Portable Compass Tester." Manual. May, 1981.

J.S. Ford "Prototype Designs for Measuring and Surveying in an Aquatic Environment." Unpublished Report. January 1981.

J.S. Ford "Current, Meters, the Effects of Unsymmetrical Responses when Operating in Waves." Unpublished Report. 1981.

E. Harrison "AWQUALABS, Shipboard Data Acquisition System (SDAS)." Manual. March, 1981.

F. Roy "Engineering Report - Study of GVAPS Mooring Cable Failure." Unpublished Report. January, 1981.

F. Roy "Manual for Lake Sediment Trap." Manual. August, 1981.

F. Roy "F.T.P. Phase A Report." Unpublished Report. February, 1982.

H. Savile "Operating Manual for Resuspended Sediment Sampler." Manual. April, 1982

#### Technical Operations

J.R. Brown "Benthic Survey of the North Channel." In support of Great Lakes Biolimnology Laboratory. Unpublished Report. 1980.

J.R. Brown "Great Lakes Biolimnology Laboratory Benthic Survey of North Channel and Georgian Bay." Unpublished Report. 1981.

J.R. Brown "Support to the Canadian Wildlife Service." Unpublished Report. 1981.

F.H. Don "Field Report for Aquatic Macrophyte Program." Unpublished Report. 1980.

F.H. Don "Operational Plan for Turkey Lakes Forest Watershed Program." Unpublished Report. 1981.

F.H. Don "Turkey Lakes Watershed Program." Unpublished Report. 1981.

J.A. Kraft "Support to Great Lakes Biolimnology Laboratory, Sault Ste. Marie." Unpublished Report. 1981.

H.B. Macdonald "Activity Summary." Technical Operations Division,  
et al. Unpublished Report. 1981.

H.B. Macdonald "Activity Summary." Technical Operations Division.  
et al. Unpublished Report. 1980.

M.R. Mawhinney "Lake Erie Physics Program." Unpublished Report. 1980.

M.R. Mawhinney "Operating Manual for Common Corers and Grab Samplers."  
Unpublished Report. 1981.

S.B. Smith "Long-Range Transport of Airborne Pollutants." In support  
of Great Lakes Biolimmology Laboratory, Sault Ste.  
Marie. Unpublished Report. 1980.

E.H. Walker "Turkey Lakes Watershed." Unpublished Report. 1980.

E.H. Walker "Toxic Substances in Great Lakes Wildlife." In support  
J.R. Brown of Canadian Wildlife Service. Unpublished Report.

#### **Western & Northern Region**

T.A. Jackson "Mercury Speciation and Distribution in a Polluted  
R.N. Woychuk River-lake System as Related to the Problem of Lake  
Restoration." In: Restoration of lakes and inland  
waters. (Proceedings of symposium held in Portland,  
Maine, Sept. 8-12, 1980), pp. 93-101. Published by U.S.  
Environmental Protection Agency, Washington, D.C. 1981.

T.A. Jackson "Dissolved and Suspended Mercury Species in the Wabigoon  
J.W. Parks River (Ontario, Canada): Seasonal and Regional  
P.D. Jones Variations." Proceedings of Second International  
R.N. Woychuk Symposium on the Interactions Between Sediments and  
J.A. Sutton Freshwater, Queen's University, Kingston, Ont., June  
J.D. Hollinger 14-18, 1981. (In press.) 1982.

B.C. Kenney "Beware of Spurious Self-correlations!" Water Resources  
Research, 37 pp., (In press.) 1982.

B.C. Kenney "On Predicting Eutrophication." NWRI-WNR, PR-80-2,  
48 pp. 1980.

E.D. Ongley "Application of Continuous-flow Centrifugation to  
D.P. Blachford Contaminant Analysis of Suspended Sediment in Fluvial  
Systems." Environment Technology Letters. (In press.)  
1982.

W.F. Warwick "The Paleolimnology of Pasqua Lake: South-eastern  
P.W. Arntfield Saskatchewan." Interim report submitted to Qu'Appelle  
Implementation Board under terms of Contract No. 23  
(1981-82). October, 1981.



### Pacific & Yukon Region

- K. Aagaard      "On the Pycnocline of the Arctic Ocean." Deep Sea Res.  
L. Coachman      28:529-545. 1981.  
E. Carmack
- E. Carmack      "Circulation and Mixing in Ice-covered Waters." In  
N.J. Untersteiner (ed.) Air-Sea-Ice Interaction, NATO  
Advanced Studies Institute Series, Plenum. 1982.
- E. Carmack      "Cooling Processes in Deep Temperate Lakes: A Review  
D. Farmer      with Examples from Two Lakes in B.C." J. Marine Res.  
1982.
- E. Carmack      "Patterns of Circulation and Nutrient Supply in a Medium  
C. Gray      Residence-time Reservoir, Kootenay Lake, B.C." Can.  
Wat. Res. J. 1982.
- R.J. Daley      "The Effects of Upstream Impoundments on the Limnology of  
E.C. Carmack      Kootenay Lake, B.C." I.W.D. Scientific Series No. 117.  
C.B.J. Gray      1981.  
C.H. Pharo  
S. Jasper  
R.C. Weigand
- D. Farmer      "Wind Mixing and Restratification in a Lake Near the  
E. Carmack      Temperature of Maximum Density." J. Phys. Oceanogr.  
11:1516-1533, 1981.
- P. Hamblin      "A Model of the Mean Field Distribution of a Dissolved  
E. Carmack      Substance within the Riverine Layer of a Fjord Lake."  
J. Wat. Res. 16:1094-1098. 1981.
- G.Y.P. Kan      "Determination of 2,4-D Butoxyethanol Ether Ester and Its  
F.T.S. Mah      Degradation Products, 2,4-Dichlorophenoxyacetic Acid and  
N.L. Wade      2,4-Dichlorophenol in Sediment." J. Assoc. Off. Anal.  
M.L. Bothwell      Chem. 64:1305-1308. 1981.
- J. Luternauer      "Geology of the Strait of Georgia." Proc. Symp.  
J.J. Clague      Oceanogr. Str. Georgia. 1982.  
C.H. Pharo  
T.M. McGee  
R.H. Linden
- R.C. Wiegand      "Some Types of Temperature Inversion Encountered in a  
E.C. Carmack      Freshwater Lake with Short Residence Time." Limnol.  
Oceanogr. 26/3. 1981.
- R.C. Wiegand      "A Wintertime Temperature Inversion in Kootenay Lake,  
E.C. Carmack      B.C." J. Geophys. Res. 86/C3. 1981.

M.L. Bothwell "Determination of Phosphorus Sufficiency and Growth Rates  
R.J. Daley of Benthic Algae in the Thompson River, B.C., using  
Continuous Flowing Troughs." IWD, Pacific and Yukon  
Regional Report. 32 p. 1981.

M.L. Bothwell "Selected Observations on the Persistence and Transport  
R.J. Daley of Residues from Aqua-Klen 20 (2,4-D) Treatments in Wood  
and Kalamalka Lakes, B.C." IWD, Pacific and Yukon  
Regional Report. 62 p. 1981.

#### In Preparation

M.L. Bothwell "An All-weather, Continuous-flow Trough Apparatus for  
Intersite Comparisons of River Periphyton Colonization  
and Production Rates."

M.L. Bothwell "Determination of Phosphorus Nutrition and Growth Rates  
S. Jasper of Benthic Algae in Rivers Using Continuous-flow Troughs:  
An intersite comparison in the Thompson River System,  
B.C."

M.L. Bothwell "Light and Dark Trough Methodology for Measuring  
S. Jasper Periphyton Colonization, Net Growth and Substrate  
Affinity."

M.L. Bothwell "A Time-course Periphyton Transplant Experiment in the  
S. Jasper Thompson River System, B.C."

E. Carmack "A Note on the Use of T/S Water-mass Analysis in Deep  
Fjord Lakes."

E. Carmack "Application of Water-mass budget to Autumn Cooling of a  
D. Farmer Riverine Lake."

E. Carmack "On the Riverine Thermal Bar."  
P. Hamblin

E. Carmack "Information and Structure in Lake Water Masses."  
J. Papadakis

E. Carmack "On Mechanisms Influencing the Riverine Circulation  
R. Wiegand Distribution of Water Masses in a Medium Residence-time  
C. Gray Lake, Kootenay Lake, B.C."  
C. Pharo  
R. Daley  
S. Jasper

E. Carmack "A Note on Intra- and Inter-annual Variability in  
R. Wiegand Apparent Vertical Diffusivity in a Deep Lake."  
E. Marles

- R.J. Daley      "Isolation of a Freshwater Planktonic Bacterial Fraction,  
S. Jasper      Free of Algae, by Nuclepore Membrane Filtration."
- C. Gray      "Effects of the Thompson River on the Nutrient Economy of  
C. Pharo      Kamloops Lake."
- R. Daley
- E. Carmack
- S. Jasper      "Primary Productivity and Effects of Riverine Flows in a  
R.J. Daley      Medium Residence-time Lake, Kootenay Lake, B.C."
- C.B. Gray
- C.H. Pharo
- E.C. Carmack
- R. Wiegand
- C.H. Pharo      "<sup>210</sup>Pb Dating of Kootenay Lake Sediments and the History  
R.W. McDonald      of Metal Mining in the Watershed."
- C.H. Pharo      "The Significance of Apatite in Fine-grained Lake  
E.C. Carmack      Sediments."
- R.J. Daley
- C.B.J. Gray
- J.D.H. Williams
- C.H. Pharo      "Metal and Nutrient Distributions in the Sediments of a  
E.C. Carmack      Short Residence-time Lake: Kootenay Lake, B.C."
- R.J. Daley
- C.B.J. Gray
- S. Jasper
- R. Wiegand
- R.C. Wiegand      "Seasonal Aspects of the Surface and Advective Heat  
E.C. Carmack      Fluxes of Kootenay Lake, B.C."
- R.J. Daley
- C.B.J. Gray
- S. Jasper
- C.H. Pharo

## **STAFF LIST**





## DIRECTOR'S OFFICE

Director - Dr. G. Keith Rodgers  
Secretary - Mrs. C. Kennedy  
Receptionist - Mrs. H. Zrostek

Science Liaison Officer - D.A. Bondy

Senior Scientist - Dr. R.A. Vollenweider  
Assistant - L. Janus  
Secretary - Mrs. S. Horne

World Health Organization/CC/SGWQ  
Manager - Dr. S. Barabas  
Secretary - Mrs. N. Clegg

Glenora Fisheries Research Station  
Scientist - Dr. P.G. Sly  
Secretary - Mrs. M. Stephen

## ENVIRONMENTAL CONTAMINANTS DIVISION

Chief - Dr. R.J. Allan  
Secretary - Mrs. E.M. Kerr  
Administrative Officer - Mr. F. Boyd  
Word Processor -

### Organics-Properties Section

Head - Dr. K.L.E. Kaiser - structure-activity correlations of organic contaminants

#### Researchers:

Dr. R.M. Baxter - biochemistry and degradation products of PCBs  
Mrs. K. Kwasniewska - biodegradation of organic contaminants and toxicity to microorganisms  
Dr. D.L. Liu - biodegradation of organic contaminants  
Dr. B.G. Oliver - sources of aquatic organic contaminants; water chlorination by-products  
Dr. R.F. Platford - physical chemistry and contaminants enhancement in water surface films

Technicians: Mr. M.E. Comba, Mrs. K.D. Nicol,  
Mr. D. Sutherland, Mrs. K. Thomson

## Organics-Pathways Section

Head - Dr. J.H. Carey               - photodegradation of organic  
contaminants

Researchers:

Mr. M.E. Fox	- persistent organic contaminants in aquatic ecosystems
Dr. E. Nagy	- fate and effects of organic contaminants in test ecosystems
Mrs. J. Metcalfe	- biological fate of contaminants
Dr. B.F. Scott	- fate and effect of organic contaminants in test ecosystems
Dr. W.M.J. Strachan	- organic contaminants in aquatic ecosystems, especially rain

Technicians: Miss L. Coletta, Mr. J.H. Hart,  
Mr. H. Huneault

## Inorganics Section

Head - Dr. R.J. Maguire                      - aquatic fate of organometallics

Researchers:

Dr. Y.K. Chau	- chemical and biological processes of organometallics in the aquatic environment; metal speciation and toxicity
Dr. D.S. Jeffries	- geochemical processes controlling lake acidification; metal geochemistry
Dr. K.R. Lum	- chemical forms of trace metals and geochemistry of particulate matter
Mrs. A. Mudroch	- chemical forms of trace metals in suspended solids and bottom sediment of aquatic ecosystems
Mr. R. Semkin	- geochemical processes controlling lake acidification

Technicians: Mr. G.A. Bengert, Mrs. T. Eguchi,  
Mr. R. Neureuther, Mr. N. Seymour, Mr. R.J. Tkacz

## Radionuclides Section

Head - Dr. R.W. Durham - impact of nuclear power development on aquatic ecosystems

Researchers:

Dr. S.R. Joshi - aquatic pathways of radionuclides

Post Doctoral Fellows:

Dr. J. Cullen - structure-activity correlations of organic  
contaminants

Technicians: Mr. J.A. FitzGerald, Miss E. Kokotich,  
Miss S. Livermore

**ANALYTICAL METHODS DIVISION**

Chief - Dr. J. Lawrence  
Secretary - Mrs. J. Burford  
Administrative Officer - Mr. S.C. Smith

Analytical Chemistry Research Section

Head - Dr. B.K. Afghan - high pressure liquid chromatography, polarography, molecular fluorescence spectrometry

Researchers:

Dr. P.D. Goulden - automation and atomic spectroscopy  
Dr. I. Sekerka - electronanalytical  
Dr. F.I. Onuska - gas chromatography and GC/MS

Technicians: Mr. J.F. Ryan, Mr. R.J. Wilkinson, Mr. J.R. Lechner,  
Mr. D.H. Anthony, Mr. K.A. Terry

Microbiology Laboratories Section

Head - Mr. B.J. Dutka - microbiological methods, toxicity screening

Researchers:

Dr. S.S. Rao - microbiology  
Dr. J.P. Sherry - mycology

Technicians: Mr. A.A. Jurkovic, Mr. K.K. Kwan, Mr. R. McInnis,  
Mrs. A. Jova, Ms. K. Walsh, Ms. A. Gadoury

Quality Assurance and Methods Section

Head - Mr. A.S.Y. Chau - method development (org. & inorg.), some  
quality control studies



## Researchers:

- Mr. V. Cheam - Methods development (Org. & Inorg.), some quality control studies  
Mr. K.I. Aspila - IJC Q.C. Program and National Q.C.  
Vacant - organic method development  
Vacant - specification generation, interregional Q.C., preservation studies  
Mr. H.B. Lee - National and IJC Q.C. (organics) standard reference materials (organics), sample storage conditions, methods evaluation

## Computer Services Section

Head - Mr. H.C. Pulley

- Ms. M. Kinder - operations supervisor  
Mr. B. Malseed - computer console operation  
Ms. U. Hamilton - computer console operator  
Ms. P. Moody - computer console operator  
Ms. J. Foley - peripheral and keypunch operator

## Clean and Hazardous Chemicals Laboratory

Dr. B.K. Afghan

## AQUATIC PHYSICS AND SYSTEMS DIVISION

- Chief - Mr. F.C. Elder  
Secretary - Mrs. S.M. Tapping  
Administrative Officer - Mr. S.C. Smith

## Basin Investigation and Modelling Section

Head - Dr. C.R. Murthy - physical limnology

- |                      |                             |
|----------------------|-----------------------------|
| Mr. F.M. Boyce       | - physical limnology        |
| Mr. J.A. Bull        | - physical limnology        |
| Mr. F. Chiocchio     | - physical limnology        |
| Dr. A.H. El-Shaarawi | - statistical modelling     |
| Mr. A.S. Fraser      | - water quality modelling   |
| Dr. E. Halfon        | - toxic substance modelling |
| Dr. P.F. Hamblin     | - physical limnology        |
| Dr. D.C.L. Lam       | - water quality modelling   |
| Mr. K.C. Miners      | - coastal zone research     |
| Mr. W.M. Schertzer   | - water quality modelling   |
| Dr. T.J. Simons      | - hydrodynamic modelling    |
| Mr. R.O.W. Kuehnel   | - physical limnology        |
| Dr. G.N. Ivey        | - physical limnology        |
| Dr. J. Jedrasik      | - physical limnology        |

Technicians:    Mr. M. Kerman                                - physical limnology  
                  Mr. D.G. Robertson                        - physical limnology

Environmental Spectro-Optics Section

Head - Dr. R.P. Bukata - lake optics and satellite studies

Mr. J.H. Jerome    - lake optics and remote sensing  
Mr. J.E. Bruton    - lake optics and remote sensing  
Mr. A.G. Bobba     - hydrogeology and remote sensing

Data Management Section

Head - Mr. J. Rogalsky - data management services

Professional:

Mr. S. Beal                                - minicomputer applications  
Mr. R. Duffield                           - data base administration  
Mrs. H. Comba  
    Supervisor                           - software development  
Mr. B. Hanson                           - software development  
Ms. J. Dowell                           - software development  
Mrs. K. Miles                           - software development  
Mrs. J. Hodson                           - software development  
Mr. A. Zingaro                           - software development  
Mrs. A. Liu                               - software development  
Mr. R. Gottinger                        - software development

Technicians:

Mr. W. Nagel  
    Supervisor                           - data archiving  
Mr. J. Byron                               - data archiving  
Mrs. J. McAvella                        - data archiving  
Miss C. Minnie                           - word processing

Long-Range Transport of Airborne Pollutants Task

Aquatic Regime Acidification:   Models and Monitoring

Dr. M.E. Thompson                       - aquatic effects of LRTAP  
Mrs. M.B. Hutton                        - data retrieval and analysis

## AQUATIC ECOLOGY DIVISION

Chief - Dr. J. Barica  
Secretary - Ms. J. Major  
Word Processor - Ms. N. Snelling  
Administrative Officer - Mr. F. Boyd

### Nutrient Pathways Section

Head - Dr. B.K. Burnison - microbial ecology, biochemistry of lake  
colloids

#### Researchers:

Mrs. A. Abbott - phosphorus kinetic studies and data analysis  
Dr. B.G. Brownlee - aquatic chemistry, nutrients  
Dr. D.R.S. Lean - ecosystem engineering, phytoplankton physiology  
Dr. G.G. Leppard - aquatic biophysics, ultrastructure of lake  
colloids  
Mr. T.P. Murphy - limnology, nutrients

Technicians: Mrs. K. Edmondson, Mrs. G.A. MacInnis,  
Mrs. D.J. Nuttley, Ms. D. Paolini

### Great Lakes Section

Head - Dr. N.M. Burns - lake chemistry, physics

#### Researchers:

Mr. M.N. Charlton - lake productivity, oxygen sedimentation  
Dr. L.L. Kalas - benthic ecology  
Dr. P.G. Manning - sediment-water nutrient interactions  
Mr. R.K. McMillan - underwater acoustics, geophysics  
Mr. F. Rosa - aquatic ecology  
Mr. R.G. Sandilands - environmental geology, underwater  
photography, computer applications in geology

Technicians: Mr. W.G. Booth, Mr. H.F.H. Dobson

### Ecological Impact Section

Head - Dr. W.A. Glooschenko - wetlands ecology, sediment geochemistry,  
peat impact

#### Researchers:

Dr. R.A. Bourbonniere - organic geochemistry  
Dr. R. Carignan - nutrient dynamics, geochemistry  
Dr. L.D. Delorme - paleolimnology  
Dr. S.R. Esterby - applied statistics, specialization in limnology  
and ecology

Researchers:

Dr. J.O. Nriagu - geochemistry, cycling of trace metals and sulfur in aquatic ecosystems  
Mr. D.S. Painter - aquatic ecology  
Mr. H.K.T. Wong - geochemistry, geochronology

Technicians: Mr. N. Arafat, Mr. R. Coker, Mrs. N. Harper, Ms. S. Lucas,  
Mrs. T. Mayer, Ms. B. VanSickle, Ms. J. Wood

Visiting Scientists: W.D. Taylor, J.-F. Gaillard

**HYDRAULICS**

Division Chief - Dr. T. M. Dick  
Secretary - Mrs. A. Mueller  
Administrative Officer - Mrs. C. Leacock  
(assigned to Hydraulics Division  
by Staff Services Division)

Engineering Services Section

Head - Mr. J. S. Ford

Instrument Research and Development Unit

Mr. R. Desrosiers  
Mr. G. Dolanjski  
Mr. E. Harrison, P. Eng., Senior Engineer  
Mr. M. Pedrosa  
Mr. J. Valdmanis, P. Eng.  
Mr. A. S. Watson, P. Eng., Senior Engineer

Equipment Research and Development Unit

Head - Mr. A. Pashley, P. Eng.

Mr. R. Boucher  
Mr. P. Carney  
Mr. F. Roy, P. Eng.  
Mr. H. Savile

Instrument Calibration and Maintenance Laboratory

Mr. K. Mollon - Supervisor  
Mr. L. Peer  
Mr. J. Thompson



### Machine Shop

Mr. D. Whyte - Supervisor

Mr. J. Bidinost

Mr. R. Chumley

Mr. K. Kalter

Mr. G. Olsen

### Drafting Office

Mr. W. D. Finn - Supervisor

Mr. M. Donnelly

Mr. P. McColl

Mr. J. Van Nynatten

Mrs. J. Field

### Environmental Hydraulics Section

Head - Dr. Y. L. Lau - River Dynamics

#### Researchers:

Dr. S. Beltaos - river ice studies

Mr. P. Engel - river engineering

Dr. B. G. Krishnappan - river dynamics

Mr. J. Marsalek - urban hydrology

Mr. H. Ng - urban hydrology

Dr. G. Tsang - ice studies

Mr. J. Wong - river ice studies

### Office Services Section

Head - Mrs. M. Hawkins - joined Division  
February, 1982

Miss D. Jacobs - divisional clerk

Mrs. E. J. Jones - machine operator

Mrs. N. Snelling - machine operator

### Shore Processes Section

Head - Dr. M. G. Skafel - Coastal Engineering

#### Researchers:

Mr. C. T. Bishop - coastal engineering

Mr. J. P. Coakley - coastal sedimentology

Dr. M. A. Donelan - air-water-interaction

Dr. N. A. Rukavina - coastal sedimentology

Mr. A. J. Zeman - geotechnical studies

Technical Services Section

Head - Mr. C. DeZeeuw

Laboratory Services

Mr. D. Fekyt  
Mr. R. Klainka  
Mr. E. Nash  
Mr. G. Voros

Environmental Hydraulics Support Unit

Mr. J. Heidt (Unit Head)  
Mr. J. Dalton  
Mr. D. Doede  
Mr. F. Dunnett  
Mr. W. Moody  
Mr. K. Salisbury

Shore Processes Support Unit

Mr. G. A. Duncan (Unit Head)  
Mr. D. Beesley  
Mr. K. Hill  
Mr. T. Nudds

National Calibration Service

Mr. C. Bil  
Miss B. Near

**TECHNICAL OPERATIONS DIVISION**

Chief - H.B. Macdonald  
Secretary - Mrs. S. Mitchell  
Administrative Officer - Mrs. C. Kennedy

Ship Survey Section

Head - P.M. Healey

Mr. B.H. Moore  
Mr. E.H. Walker  
Mr. S.B. Smith  
Mr. G.J. Koteles  
Mr. P.R. Youakim  
Mr. R.J. Hess  
Mr. G.G. LaHaie  
Mr. J.A. Kraft  
Mr. C. Bisutti

Limnological Instrumentation Section

Head - Mr. J.A. Diaz

Current Meters & Data Abstraction Unit

Head - Mr. J.A. Tyler

Mr. J.L. Dunn

Field Instruments & MET Systems Unit

Head - Mr. E.G. Smith

Field Survey Section

Head - Mr. W.B. Taylor

Mr. M.R. Mawhinney - Senior Field Officer

Mr. L.E. Benner

Mr. G.D. Bruce

Mr. J.E. Tozer

Mr. K.J. Hill

Mr. T.J. Carew

Mr. W.D. Hunt

Underwater Operations Unit

A/Head - Mr. F.H. Don

Rigging Unit

Head - Mr. L.J. Lomas

Mr. H.E. Greencorn

Mr. G.M. Perigo

**STAFF SERVICES DIVISION**

Chief - Mr. J.D. Smith

Secretary - Mrs. C. Kennedy

Financial Services:

Head - Mr. A.B. Mitchell

Support Staff: Mrs. B. Titley, Mrs. Y. Hutton  
Ms. E.A. King, Mr. D. Jefferson  
Mr. R. Haswell, Mr. D. Foran

### Central Registry

Supervisor - Mrs. E. Rae

Support Staff: Mrs. M.T. Solvason, Mrs. J.A. Sims

### Materiel Management

Head - Mr. C.F. Hicks

Support Staff: Mr. J.P. Mellon, Mr. D.M. Niles,  
Mr. S.E. Hicks, Mrs. M. Eadie,  
Mr. W. Coventry

### Building and Property Services

Head - Mr. D.F. Stewart

Safety Officer - Mr. R.J. Gray

Nurse - Miss C. Shulver

Support Staff: Mr. J.C. Stewart, Mr. D.J. Smit,  
Mr. C.K. Platt, Mr. K. Taylor,  
Mr. F. Adams, Mr. A.K. Allaby,  
Mr. M. Connors, Mr. D.W. Clewley,  
Mr. J.P. Denomme, Mr. W.A. Johnson,  
Mr. T. Comiskey, Mr. R.J. McCurdy

### Library Services

Head - Ms. E. Dowie

Support Staff: Ms. P. Haley, Mrs. J. Tinney,  
Mrs. K. Finch, Ms. P. Bennett

### Information Unit

Officer: Mrs. I. MacLeod

## **WESTERN AND NORTHERN REGION**

Chief - Dr. E.D. Ongley

Researchers:

Dr. T.A. Jackson - metal biogeochemistry, nutrient geochemistry

Dr. B.C. Kenney - wind generated mixing processes, physical  
limnology

Dr. W.F. Warwick - paleolimnology, benthic studies



Technicians:

Mr. J.C. Mollison - Physical limnology technologist  
Mr. J.P. Tisdale - Geochemical technologist  
Mr. R.N. Woychuk - Biogeochemical technologist

**PACIFIC AND YUKON REGION**

Chief - Dr. R.J. Daley  
Secretary - Ms. S. Roberts

Researchers:

Dr. M.L. Bothwell - benthic ecology  
Dr. E.C. Carmack - physical limnology  
Mr. C.B.J. Gray - chemical limnology  
Mr. S. Jasper - biological limnology  
Dr. C. Pharo - sedimentology and geochemistry  
Mr. R.C. Wiegand - physical limnology

Technicians:

Miss V.A. Chamberlain, Mr. R.A. Kirkland, Mr. E.W. Marles,  
Mrs. K. Suzuki

#### COMMITTEE MEMBERSHIP



## **COMMITTEE MEMBERSHIP**

### Director's Office:

G.K. Rodgers	International Joint Commission Science Advisory Board IWD Research Subventions Committee Water Research Advisory Committee Canada-Ontario Rideau Trent System (CORTS)
R.A. Vollenweider	Technical Bureau, OECD Cooperative Program on Eutrophication - Chairman Senior Scientific Advisory Panel on Eutrophication (UNESCO) - Chairman Subcommittee on Water, National Research Council Associate Committee on Scientific Criteria for Environmental Research Working Group on Reservoir Eutrophication Control in Warm Climates (WHO) Editorial Board of the "Memorie dell' Istituto Italiano di Idrobiologia", Verbania-Pallanza, Italy Editorial Board "WHO-Water Quality Bulletin" Scientific Advisory Committee "Cervia Ambiente", Italy
S. Barabas	Elected Fellow of the Chemical Institute of Canada Faculty Advisory Board of Ryerson Polytechnical Institute
P.G. Sly	Lake Ontario Working Group, Great Lakes Fisheries Commission Workshop of Lake Trout Research, August, 1983 Director on the Board of IAGLR Associate Editor, Canadian Geotechnical Journal Fellow, Rawson Academy

### Environmental Contaminants Division

R.J. Allan	Canada-U.S. Niagara River Study Canada-Ontario English-Wabigoon Mercury Study GLWQA, Lakes Toxic Contaminant
J.H. Carey	GLWQA, Capital Equipment
Y.K. Chau	Standards Council of Canada ASTM Sediment Analysis Group



R.W. Durham	Ontario Region EARP GLWQ Radioactivity Working Group
D.S. Jeffries	Algoma Acid Rain Steering Committee
K.L.E. Kaiser	IJC-SAB Task Force on Non-Phosphate Detergents
D.S. Liu	UN-FAO Marine Fouling Group Standards Council of Canada ASTM Oxygen Uptake Group
R.J. Maguire	Environmental Monitoring of Forest Insect Control Operations NRC Environmental Secretariat Panel ECA Chemical Evaluation
A. Mudroch	Canada-U.S. Niagara River Study
E. Nagy	AGRAD Working Group on Fate of Oil
B.F. Scott	International Standards Organization AGRAD Working Group on Fate of Oil DOE-Ontario Environmental Emergency Team
W.M.J. Strachan	OECD Chemical Testing Program GLWQA, Aquatic Ecosystems Objectives

#### Analytical Methods Division

B.K. Afghan	Chairman, Subcommittee 2 on Canadian Advisory Committee on ISO/TC147 Member, Canadian Advisory Committee for Standards Council of Canada Task Group Chairman for various ASTM task groups: Nutrients in Sediment, Chlorinated dioxins, liquid chromatography and ATP (these task groups form an integral part of ASTM Subcommittees 6, 7 and 24).
K.I. Aspila	Chairman, Data Quality Work Group - IJC Water Quality Programs Committee LRTAP Quality Assurance Subgroup - Federal-Provincial Committee on LRTAP Chairman, Quality Control Work Group - LRTAP
A.S.Y. Chau	Task Group Chairman - D:19 on Water - ASTM General Referee, Committee E, Water Methodology - AOAC Member, Quality Assurance Committee - AOAC Coordinator for Water and Sediment, FICP Check Sample Programs - FICP

V. Cheam

Member, Analytical Methods Work Group - LRTAP

B.J. Dutka

Chairman, ASTM Subcommittee D19:24

Chairman, Task Group D19:24:01.19 - Legionella

Chairman, Task Group D19:24:06.06 - Sulphate  
reducing bacteria

Member of Task Group D19:24:06.07 - Toxicity  
Tests

D19:24:08.08 - Mutagen Tests

D19:24:08.09 - Epifluorescence Microscopy

D19:24:08.18 - Heterotrophic bacteria

D19:24:04:02 - Membrane Filters

Member - ASTM D19 Executive Committee

Member - ASTM D19 Long Range Study Committee

Member of Joint Task Group, Section 907, APHA  
Standard Methods

Chairman of CAC/ISO/TC147

Chairman, Canada ISO/TC147/SC4 - Microbiology

Chairman and International Secretariat,  
ISO/TC147/SC4/WG-9 - Membranes

Chairman and International Secretariat,  
ISO/TC147/SC5/WG7 - Mutagens

Canadian Task Group Leader, ISO/TC147/SC4/WG1 -  
Enumeration of microorganisms

ISO/TC147/SG4/WG2 - Coliform

ISO/TC147/SC4/WG3 - P. aeruginosa

ISO/TC147/SC5/WG5 - Bacterial Toxicity

Chairman, First International Symposium on  
Toxicity Testing Using Bacteria  
Symposium Committee

Associate Editor, Journal of Great Lakes  
Research

Editorial Board - Water Quality Bulletin

Microbial Problems Committee of the American  
Water Association

P.D. Goulden

CCIW Representative on IWD Committee on  
Technical Training

J. Lawrence

Member, Great Lakes Toxic Chemicals Committee

Member, Analytical Capability Committee

Member, Associate Committee on Scientific  
Criteria for Environmental Quality

Co-Chairman, RMCC - Quality Assurance  
Sub-Group

H.B. Lee

Associate Referee for Herbicides - Committee  
E, Water Methodology - AOAC

Associate Referee for Organo-phosphate  
Committee E, Organo-phosphate - AOAC

F.I. Onuska	Panel Member on PAH in Water - Subcommittee on Water of NRCA Associate Committee on Scientific Criteria for Environmental Quality
H.C. Pulley	VIM (CDC Computer User's Group) Applications and Graphics Products Committee
S.S. Rao	Chairman, ASTM - Task Group D19:24:06:09 Task Group D19:24:06:10 Member, Advisory Committee - Masters Program, University of Toronto. Sponsored by Dr. A.P. Zimmerman (Biology Dept.)

Aquatic Physics and Systems Division

A.G. Bobba	Toronto Hydrology Working Group
F.M. Boyce	Associate Editor, Atmosphere Oceans (Journal of Canadian Meteorological and Oceanographical Society) IFYGL Water Movements Panel (Canadian Co-chairman)
J.E. Bruton	Limnology Working Group, CACRS, Secretary Computer Compatible Tapes Usage Working Group, CACRS Toronto Hydrology Working Group
R.P. Bukata	Chairman, Limnology Working Group, Canadian Advisory Committee on Remote Sensing Representative, CCIW Remote Sensing Specialty Centre, Canadian Advisory Committee on Remote Sensing
F.C. Elder	Canada-U.S. Memorandum of Intent, LRTAP Workgroup I, Impact Assessment Federal/Provincial LRTAP Research and Monitoring Coordinating Committee, Co-chairman of Aquatic Effects Sub-committee Environmental Conservation Service, LRTAP Steering Committee, IWD Member
A.H. El-Shaarawi	Vice Chairman, Biometrics Subcommittee Head, Descriptive Mathematics Section, American Society for Testing of Materials

E. Halfon	Directors Board, International Society of Ecological Modelling, North American Chapter PhD. Committee, State University of New York, Binghamton, (Dept. of Systems Science).
P.F. Hamblin	Associate Editor for Physical Limnology Journal of Great Lakes Research from its inception in 1975 to present Member of a supervisory committee of a doctoral candidate in civil engineering, McMaster University
D.C.L. Lam	Chairman, Programs Committee, Canadian Applied Mathematics Society (1981/82) Editorial Board - International Journal of Advances in Water Resources PhD. Candidate Supervisory Committee, Civil Eng. Department, McMaster University Vice-president, Executive Council, Canadian Applied Mathematics Society (1981/82).
C.R. Murthy	Member, DOE Working Group on Environmental Codes of Practice for Steam Electric Generating Stations Co-convenor, SCOR Working Group on Coastal and Estuarine Regimes, XVII IUGG General Assembly (Large Lakes Session) IFYGL Water Movements Panel IWD/NWRI/NHRI Research Coordination Committee
T.J. Simons	IFYGL Water Movements Panel.

Aquatic Ecology Division

N. Arafat	LRTAP Scientific Committee
J. Barica	Great Lakes Working Group, Eutrophication Sub-Group Plains Aquatic Research Executive Committee Group
Dr. R.A. Bourbonniere	DOE Peat Committee



Dr. L.D. Delorme	Canadian Committee on Climatic Fluctuations and Man IWD Contact, AES Carbon Dioxide/Climate Advisor Honorary Consultant - Survival Service Commission of the International Union for the Conservation of Nature & Natural Resources; Survival Service Commission: UNESCO
Dr. S.R. Esterby	ASTM Biometrics Sub-committee on Water (D.19.20)
Dr. W.A. Glooschenko	DOE Peat Committee DOE Coal Group National Wetlands Working Group Canadian Committee on Ecological Land Classification
D.R.S. Lean	Standard Methods Advisory Group
J.O. Nriagu	Canadian National Committee for SCOPE SCOPE Scientific Committee on Metal Cycles International Committee for Symposia on Environmental Biogeochemistry Organizing Committee, 11th International Sedimentology Congress Chemical Geology, Editorial Board Tellus, Editorial Board Science of the Total Environment, Editorial Board Editor, Advances in Environmental Science and Technology

#### Hydraulics Division

S. Beltaos	IAHR Working Group on Thermal Regimes IAHR Working Group on Ice Jams CSCE Hydrotechnical Research Committee
T.M. Dick	International Association for Hydraulics Research (IAHR) Council Member 1982/83 Association internationale de recherches hydrauliques International Association for Great lakes Research (IAGLR) Board Member & Treasurer FWD Research Coordination Committee - Chairman Canadian Society for Civil Engineering - Chairman, Keefer Medal Selection Committee

T.M. Dick	<p>Editorial Board (WHO) Water Quality Bulletin  Associate Committee for Research on  Shoreline Erosion and Sedimentation  (ACROSES) - NRC - Chairman  Comité associé de recherche sur l'érosion et  la sédimentation littorales (CARESL) -  CNR - President</p>
M. Donelan	<p>American Meteorological Society's committee  on "Interaction of the Sea and  Atmosphere"  "Air-Sea Interface Working Group" of the  Aadarsat (Radar-satellite) Oceans Team</p>
J.S. Ford	<p>Mohawk College Technology Working Group  Scientific Equipment Development Working  Group</p>
B. Krishnappan	<p>Bridge Hydraulics Project Committee of Roads  and Transportation Association  CSCE Task Force on Mixing Processes in Rivers</p>
Y.L. Lau	<p>Canadian Society of Civil Engineering:  Hydrotechnical Division Research  Committee</p>
J. Marsalek	<p>Working Group on Urban Hydrology (under the  International Hydrological Program of  UNESCO)  Urban Water Resources Research Council of  ASCE  Editorial Board of "Eau du Québec" Journal  Stormwater Management Task Force of CSCE  Technical Committee for the Waterfront River  Basin Study</p>
H.Y. Ng	<p>The Association of the Professional Engineers  of Ontario</p>
A. Pashley	<p>PILP - Program for Industry/Lab Projects</p>
N. Rukavina	<p>PhD. Supervisory Committee - Dept. of  Geography, McMaster University  Chairman, Coastal Workshop 3 Committee  Marine Region Workshop Committee - Parks  Canada  Organizing Committee - International  Association of Sedimentologists 11th  International Congress</p>
M. Skafel	<p>Scientific Equipment Development Working  Group</p>

G. Tsang	NRC Subcommittee on Hydraulics of ice covered rivers Niagara International Board of Control, Ice Specialist Panel
J. Valdmanis	Current Meter Measurement Committee (affiliated with IEEE)
A.J. Zeman	NRC Subcommittee on Marine Geotechnical Engineering Organizing Committee, 2nd Canadian Conference on Marine Geotechnical Engineering Organizing Committee, NWRI Coastal Workshop 3









Canada



Environment  
Canada

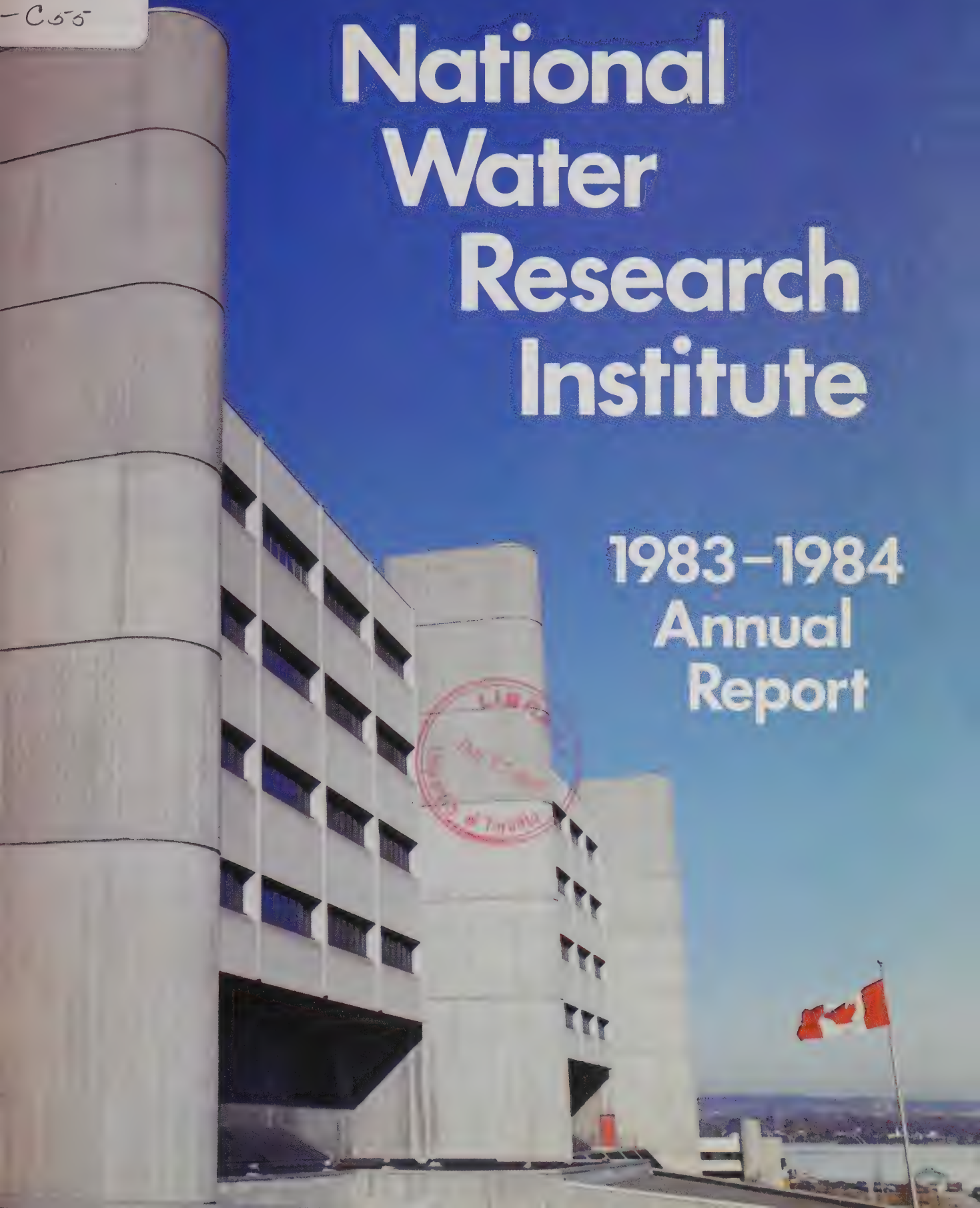
Environnement  
Canada

Government of Canada  
Produced by the  
National Water Research Institute

CA1  
MT64  
-C55

# National Water Research Institute

1983-1984  
Annual  
Report





---

**Editor:** Dr. J.M. Barica

**Production Group:** Mrs. N.J. Clegg  
Mr. W.D. Finn  
Mrs. M.R. Hawkins  
Mr. P.C. McColl

Cover photograph by W.D. Finn

On peut aussi obtenir cette publication en français.

**NATIONAL WATER RESEARCH INSTITUTE**

**1983-1984  
Annual Report**

**Address:**

National Water Research Institute  
P.O. Box 5050  
Burlington, Ontario  
Canada L7R 4A6

## **NATIONAL WATER RESEARCH INSTITUTE**

### **N O T E**

NOTICE is hereby given that mention of any product or material in this publication is not to be taken as indicating that the National Water Research Institute in any way approves, recommends or endorses any such product or material. No mention shall be made of the National Water Research Institute or of this publication in any advertising, sales promotion, reports or other written or graphic material which would indicate or imply that the National Water Research Institute approves, recommends or endorses any product or material mentioned herein, or which has as its purpose an intent to use the name of the National Water Research Institute or this publication as a means, directly or indirectly, of causing, aiding or enhancing the sale or use of any such advertised product or material.

# TABLE OF CONTENTS

	Page
<b>FOREWORD</b> .....	1
<b>WRI ORGANIZATION CHART</b> .....	2
<b>INTRODUCTION</b> .....	3
<b>HIGHLIGHTS</b> .....	5
Water Management Research .....	5
Toxic Chemicals .....	6
Long-Range Transport of Airborne Pollutants .....	7
Canada-U.S. and Interjurisdictional Water Management .....	8
<b>RECTOR'S OFFICE</b> .....	9
Senior Scientist .....	9
Science Liaison Office .....	9
Habitat Studies .....	9
World Health Organization Collaborating Centre on Surface and Ground Water Quality .....	10
Staff List .....	11
Committee Membership .....	11
Publications .....	12
<b>AQUATIC ECOLOGY DIVISION</b> .....	13
Ecological Impact Section .....	13
The Great Lakes Rehabilitation Section .....	14
Nutrient Pathways Section .....	16
Staff List .....	18
Committee Membership .....	19
Publications .....	19
<b>AQUATIC PHYSICS AND SYSTEMS DIVISION</b> .....	21
Physical Limnology Section .....	21
Environmental Simulation Section .....	22
Environmental Optics Section .....	24
Data Management Section .....	25
Staff List .....	26
Committee Membership .....	26
Publications .....	27
<b>ENVIRONMENTAL CONTAMINANTS DIVISION</b> .....	29
Organics Pathways Section .....	29
Organics Properties Section .....	31
Inorganics Section .....	32
Radionuclides Section .....	33
Acid Deposition Section .....	34
Staff List .....	35
Committee Membership .....	36
Publications .....	36



<b>ANALYTICAL METHODS DIVISION</b> .....	39
Analytical Chemistry Research Section .....	39
Quality Assurance and Methods Section .....	40
Microbiology Laboratories Section .....	41
Computer Services Section .....	43
Staff List .....	43
Committee Membership .....	44
Publications .....	45
<b>HYDRAULICS DIVISION</b> .....	47
Environmental Hydraulics Section .....	47
Shore Processes Section .....	50
Technical Services Section .....	54
Engineering Services Section and Manufacturing and Technical Development Section .....	54
Drafting Services Section .....	57
Office Services Section .....	57
Staff List .....	57
Committee Membership .....	58
Publications .....	59
<b>NWRI PACIFIC AND YUKON REGION</b> .....	62
Staff List .....	65
Committee Membership .....	65
Publications .....	65
<b>NWRI WESTERN AND NORTHERN REGION</b> .....	66
The Qu'Appelle River System .....	66
South Indian Lake (SIL) .....	66
The North Saskatchewan River System .....	67
Wabigoon-English River System .....	68
Technology Transfer .....	69
Staff List .....	69
Committee Membership .....	69
Publications .....	69
<b>TECHNICAL OPERATIONS DIVISION</b> .....	70
Ship Survey Section .....	70
Field Survey Section .....	70
Limnological Instrumentation Section .....	73
Staff List .....	75
<b>STAFF SERVICES DIVISION</b> .....	77
Administration Section .....	77
Building and Property Services Section .....	77
Materiel Management Section .....	77
Finance Section .....	77
Library Section .....	77
Central Registry Section .....	77
Staff List .....	77



Your file    Votre référence

Our file    Notre référence

This is the third comprehensive summary of the programs of the National Water Research Institute (NWRI) of the Inland Waters Directorate, Canada Department of the Environment. These programs address a wide variety of research and technical problems or opportunities associated with the protection, enhancement, development or sustained use of Canada's inland water resources.

In this edition, the staff describe the results of recent work, and outline our on-going activities in the fields of environmental contaminants, hydraulics, aquatic ecology, instrumentation, physical limnology, analytical chemical methodology and microbiology. Because many aspects of our field work, engineering/manufacturing, and support services are unique, these are also described.

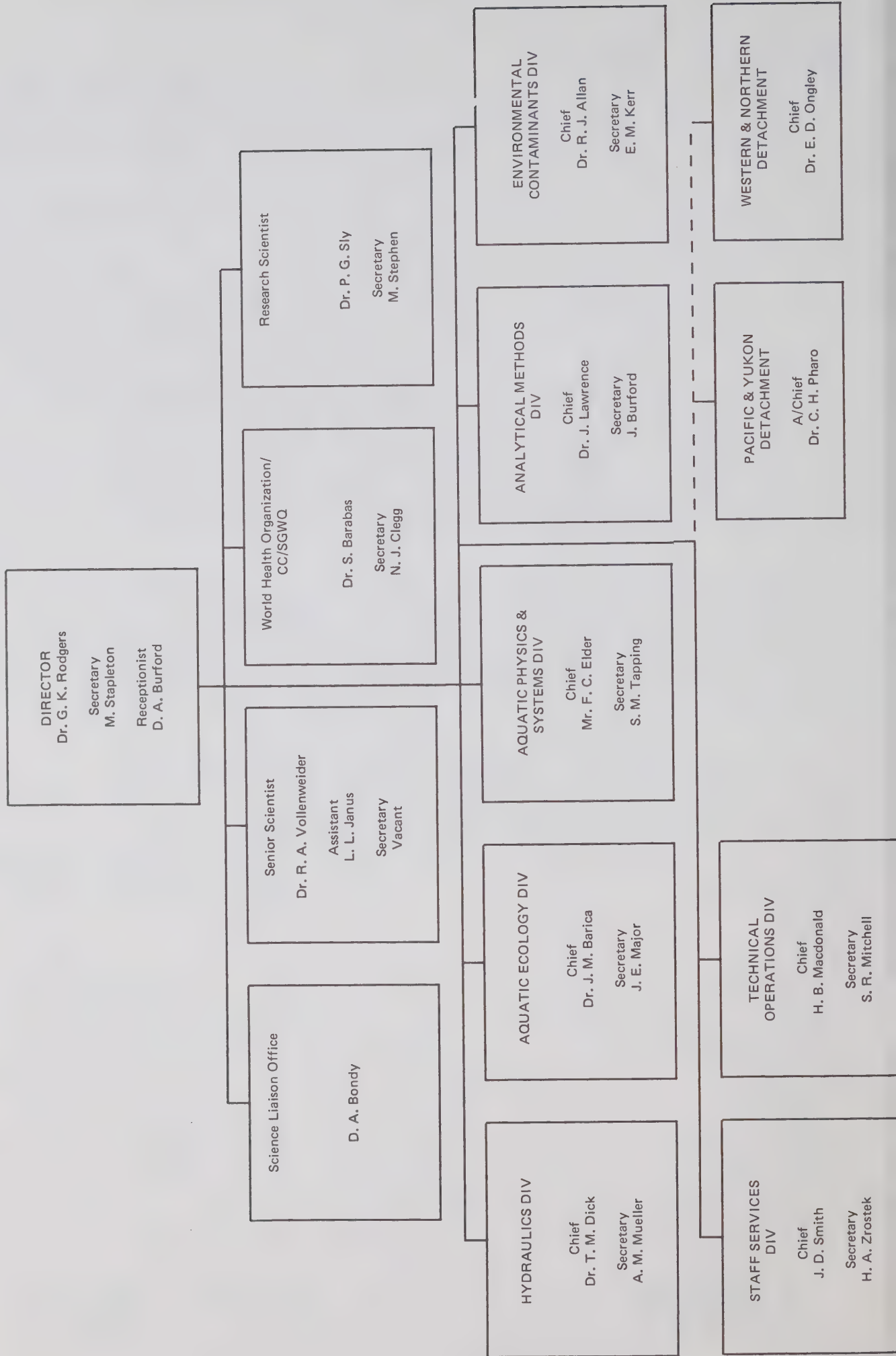
Here we present the results of a dedicated effort to advance, apply and disseminate knowledge of scientific merit and practical importance that will be of value to our clientele in federal and provincial agencies, in universities and industry, and of value to the public at large.

It is my pleasure to introduce you to this record of achievement.

Dr. G.K. Rodgers  
Director

# ORGANIZATION CHART

## NATIONAL WATER RESEARCH INSTITUTE



## **INTRODUCTION**

The National Water Research Institute (NWRI) of the Inland Waters Directorate is an environmental research organization headquartered and largely based at the Canada Centre for Inland Waters (CCIW) in Burlington, Ontario. Two regional units of NWRI are based in Vancouver and Winnipeg. The Institute is part of the Department of the Environment for Canada.

Programs are implemented by five research divisions — Aquatic Ecology, Aquatic Physics and Systems, Analytical Methods, Environmental Contaminants, and Hydraulics and in the two regional units.

NWRI staff have been successful in leading studies that have drawn new subject-specific resources to the Institute in the areas of contaminants and eutrophication, contracting into the Hydraulics laboratory, long-range transport of airborne pollutants (including acid rain), aquatic impact of energy development, infestation by aquatic weeds, and investigations for the Great Lakes Water Quality Agreement.

The National Water Research Institute carries out a program of research and development designed to meet the general objectives of providing the necessary information and understanding of water systems for water management problems or opportunities in Canada. Building on this program of research and development, it seeks to advance, apply and disseminate scientific and engineering knowledge in the fields represented by the research programs. The work includes field and laboratory research on problems of natural or man-modified aquatic regimes. Problems investigated are of national scope or are related to specific geographical sites referred by other agencies within or from outside the Department of the Environment. Part of the total program is the provision of advice or information through publications, services on a consultative basis to other government agencies, service on scientific and technical committees of the government or government-supported institutions such as the International Joint Commission, and the provision of scientific services such as calibrations, analytical services instrument testing, methodology documentation or interlaboratory quality control.

Although the headquarters is at CCIW, detachments of NWRI are located in Winnipeg and Vancouver. Also, one senior staff member has been assigned to the Glenora Research Station of the Ontario Ministry of Natural Resources and a small unit working on the Long Range Transport of Airborne Pollutants is based near Sault Ste. Marie, Ontario. There are many other temporary field sites occupied across Canada as the need arises.

Research in NWRI divisions, which are grouped by scientific disciplines, is carried out within the larger framework of multidisciplinary and interdepartmental national programs, several primarily:

### **Canada-U.S. and Interjurisdictional Water Management**

To resolve interjurisdictional water resource problems and realize interjurisdictional water resource opportunities in accordance with national interests. This includes problems and opportunities relating to water quality management, river basin planning and implementation of plans, and water resources utilization.

### **Water Management Research**

To advance knowledge and provide information and understanding required for the solution of water management problems and the realization of water development opportunities.

### **Toxic Chemicals**

To provide information on the presence of Toxic Chemicals in the environment, the pathways of these chemicals in the aquatic environment and knowledge of their actual and potential impacts on the environment.

### **Long Range Transport of Airborne Pollutants**

To evaluate impacts of airborne pollutants on aquatic ecosystems including their capacity to buffer acidification in lakes and rivers, wildlife populations and lands, and monitor the effects of such impacts.





# HIGHLIGHTS

## WATER MANAGEMENT RESEARCH

- A major finding of the Lake Erie water quality modelling study indicated that the lake is recovering from eutrophy as a result of the phosphorus reduction program but the oxygen depletion phenomenon remains largely under the influence of natural weather processes. Only when the contribution from these natural processes are identified could the man-made effects be quantified. A new modelling methodology was developed to reconstruct the lake thermal structures, directly linking the climatological forcing functions to the thermal layer thicknesses which in turn affect the oxygen content in the lake. Verified with observed data collected over a twelve-year period, the model results now depict the benefits of the phosphorus reduction program on the oxygen depletion situation under normal, favourable and adverse weather conditions.
- A monograph was prepared and published on 'Effluent Transport and Diffusion Models for the Coastal Zone' to provide the necessary background for the interfacing of different computational methods and physical models for investigators of coastal water quality and for other multidisciplinary concerns in the coastal zone.
- The movement of particles carrying nutrients and contaminants was studied with sediment traps in Lake Ontario. These studies resulted in three reports on the movements of material loaded from the Niagara River and resuspended from the bottom of Lake Ontario. Results indicate that there is much resuspension of bottom sediments which may enhance the availability of nutrients and contaminants in the lake.
- Development and construction of oxygen profiling equipment has resulted in the use of a prototype system in surveys of Lake Erie during 1983. The new equipment uses electronic sensors and a microcomputer to control the lowering winch, interpret the signals, and record the data on diskettes.
- Studies began on the potential impact of drainage waters from peatlands upon receiving water bodies including lakes and streams. Sampling was carried out in Nova Scotia, Quebec and Ontario to obtain peat and drainage water from contrasting sites. Initial work on organic compounds includes isolation of hydrophobic and hydrophilic acids.
- The lime application to Frisken Lake as a whole lake restoration method removed 97% of the phosphate and 80% of the chlorophyll-a from the epilimnion. In the hypolimnion, the decomposition of the algae reduced the pH and much of the precipitated phosphate-carbonate complex redissolved.
- Eurasian watermilfoil research (*Myriophyllum spicatum*) has concentrated on assessing the long-term impact of harvesting on milfoil regrowth and attempting to determine the mechanism behind the decline of milfoil in several lakes in Ontario.
- *Cladophora* research concentrated on examining the nearshore environmental conditions along the north shore of Lake Ontario that affect *Cladophora* growth. A computer simulation model was used to assess the growth potential of various sites. The model inputs are temperature, turbidity, and phosphorus. The outputs are tissue phosphorus, phosphorus uptake, net and gross photosynthesis and biomass. The model will be used to evaluate the importance of local nutrient inputs compared to the nutrient supply in open lake water.
- It was demonstrated that the beaching and subsequent decay of *Cladophora* in the Hamilton to Oakville area of Lake Ontario coincided with a recent taste and odor event in the local water supply. Geosmin was identified in some of the finished water from the water treatment plant.
- Lake phosphorus dynamics techniques have been developed to simulate phosphorus concentrations that naturally occur in lakes and to predict changes resulting from lake manipulation. Excellent results were obtained for the Qu'Appelle Lakes in Saskatchewan and for Lake Washington.
- Water exchange between Long Bay and South Indian Lake in Northern Manitoba was directly measured under ice. Winter circulation is an important factor that influences environmental response to lake level changes produced by hydroelectric development.
- A press release was issued by the Ministers of Environment and National Health and Welfare (NH&W) on *Legionella* bacteria studies being carried out by Microbiology Laboratories staff and NH&W staff. As a result of this press release, numerous phone interviews were held with newspaper reporters as well as television interviews.
- Methods for the determination of acidity, alkalinity and dissolved oxygen by flow injection analysis had been developed. These techniques could eventually replace colormetric methods for many parameters.
- The success of the joint Weyerhaeuser Canada/Environment Canada research project to study the causes of excessive benthic algal growth in the Thompson River has resulted in a continuation of the study to define more precisely the relationships between benthic algal growth rate and phosphorus concentration. This project uses a continuously flowing trough methodology in which the flow of natural river water can be precisely regulated. The substrate is optimal for algal accumulation. Light-dark comparisons can be made, and the concentration of nutrients in the water can be accurately controlled.

- Seasonal chemical and physical monitoring of the Yukon River's headwater lakes has confirmed the oligotrophic nature of these lakes. Many opportunities for research into physical processes and sedimentation in high energy river-lake couplings with seasonal ice cover are being explored. Controls on sediment dispersal and deposition in Lake Laberge, where the river flows along the lake as a buoyant plume, contrast sharply with the same processes in Kluane Lake, where the highly turbid plume of the Slims River plunges down the delta face to flow along the bottom as a well-defined turbid plume.
- The annual growth and decay of ice in Lake Laberge and the adjacent upstream and downstream sections of the Yukon River and its effect on the physical, chemical, and biological limnology of Lake Laberge is being examined in detail in a joint venture with Water Resources Branch. The first season's field work is nearly complete and results are very encouraging.
- A Portable Aquatic Video System was developed to inspect underwater objects, especially when an ice cover exists, and facilitated with the development of an all-weather, watertight video system. The prototype equipment is easily transported and has been used by survey teams on rivers in New Brunswick and in the Arctic.
- A Meteorological Data Buoy was constructed. Measurements of interface phenomena were made accessible in one package with the MET II system. It not only measures selected variables in the air such as wind speed and direction, air temperature and radiation flux, but it also obtains the wave height and frequency statistics as well as the wave energy direction. This buoy is a significant development for instrumenting lakes in any part of Canada. It is equally useful in ocean applications.
- An Automatic Water Sampler was also developed. This device collects and stores samples of water for later analysis on pre-established daily or hourly schedules. Prototypes are in place at Niagara-on-the-Lake, Wolfe Island, and Fort Erie.
- Fundamental studies on meander development have shown that turbulence is not necessary for meanders to develop. Furthermore, the process is not entirely stochastic and is probably governed by a deterministic relationship. These findings permit investigation to focus on the sediment processes as being the deterministic controlling variable for meanders and are essential to predicting the behaviour and flooding of a river which is subject to sediment supply changes or diversion of flow.
- Sediment transport under an ice cover is significant for assessing the impact of northern development or environmental assessments elsewhere. It was found that an ice cover greatly reduces the bottom sediment transport. Moreover, with the correct interpretation, the methods used to calculate transport in open channel flow are applicable to ice-covered flows.
- The River Mixing Model (RIVMIX) is a very versatile model which is able to delineate mixing zones in rivers or to determine the transverse, vertically averaged concentration gradients downstream from a river outfall. It can transfer observed gradient of pollutants to a point downstream. This model is useful for designing or analyzing the results of river sampling programs. It can be used for any plan form such as meanders or any cross section.
- A method to accurately predict the behaviour of a surge wave after an ice jam breaks has been developed. The numerical model MOBED was used to analyze the behaviour of a field case study and it was found that the model provided a good estimate of surge speeds and water elevations. It also could be used to investigate the effect on the mobile bed. Subsequent tests in the laboratory confirmed that MOBED provides a very satisfactory analysis of surges with ice.
- A Frazil Ice Instrument has been developed after several years of work and a prototype instrument to measure frazil ice concentrations has been manufactured. It provides a means to make real progress in ice research and is highly significant for investigation of northern waters.
- A theory to predict the transfer of gas at the air-water interface has been developed which incorporates the effect of breaking waves. Data tends to corroborate the theory which is highly significant for understanding limnological processes as well as being of importance for global weather models. This fundamental study could have significant impact on air-water exchange models.
- A theoretical method to obtain the concentration of resuspended sediment by waves has been confirmed by laboratory tests. The model gives a time-averaged concentration as a function of depth, knowing the wave variables such as wave height, period, and mean water depth, and the sediment variables of grain size and specific gravity. This development is necessary to correctly predict transportation and sedimentation in lakes. Such knowledge is essential to evaluate the impacts of changing the water level of a lake and may be significant for calculations of chemical transfers between sediment and water.

## **TOXIC CHEMICALS**

- A Special Issue of the Journal of Great Lakes Research dealing with the Niagara River-Lake Ontario Pollution Problem was published in June, 1983. Significant findings included evidence of apparent recent reduction in loading to Lake Ontario of several toxic organic chemicals and toxic metals; the presence of a suspended sediment enriched Nepheloid layer extending tens of meters above the bottom of Lake Ontario and possibly of significance to chemical recycling and persistence in the lake, and the concentrations of contaminants in various lower organisms which may control chemical bioaccumulation via food webs.



Organotin and other organometallics were increasingly discovered in several Great Lakes media using analytical methods newly developed. The occurrence of diethyl-, triethyl-, and tetraethyllead in fish caught in contaminated areas was reported for the first time.

Computer programs correlated bond strengths of toxic organic chemicals with toxicity data for lower organisms as part of the Structure Activity Correlation technique to assess the dangers of specific chemicals.

Leeches which are common in Canadian rivers have been shown as potential biomonitors of toxic organic chemicals.

2,4-D was shown primarily to be photochemically degraded and that disappearance was rapid in experimental ponds.

At the Niagara River inflow area of Lake Ontario, amphipods were shown to be active bioaccumulators of toxic organic chemicals.

The photochemical degradation of the lampricide TFM, which was predicted from previous laboratory studies, was confirmed both in a field test pond and by sampling of a stream during TFM treatment.

Suspended sediments taken from the North Saskatchewan River during a summer storm event indicate a complex set of sources and pathways for organic contaminants. Results show various contaminants have reached Tobin Lake with serious effects on the benthos.

Toxic contaminants have compounded serious eutrophication problems in prairie lakes and have contributed to decimation of chironomid communities and other lower members of the food chain in Pasqua Lake, Saskatchewan.

Processes of biogeochemical cycling of mercury species and its impact on the foodweb have been identified for Northern Manitoba Reservoirs.

A very successful "First International Symposium on Toxicity Testing Using Bacteria" was held at NWRI on May 17-19, 1983. The emphasis of this Symposium was on the reliability, speed and cost effectiveness of microbial toxicity screening procedures. A method was developed for the separation of 22 isomers of tetrachloro-dibenzo-p-dioxins using narrow bore wall coated open tubular gas chromatography.

Toxaphene methodology based on solid probe and selected ion monitoring has been developed. Up to 30 samples per day can be analyzed by this technique.

The first lake sediment reference material for 6 chlorobenzenes and hexachlorobutadiene was completed.

## **LONG-RANGE TRANSPORT OF AIRBORNE POLLUTANTS**

The "target loading" of 20 kg/ha-yr of sulphate that has been accepted for the Canadian International negotiation for sulphur emission control was derived through application of the Thompson-Henriksen model developed within NWRI and adapted to the water chemistry data base of eastern Canada. While this "target load" must be considered as preliminary, it forms the basis for initiation of control measures to correct the environmental acidification concern.

Variations in sulfur isotopes and in the Se/S ratios have been used to study the sources, dispersion pathways and ultimate sinks for the two elements in lakes of northern Ontario. The data obtained suggest that sulfur is relatively immobile in sediments and that the accumulation of excess sulfur reflects the increasing inputs of pollutant sulfur into the lakes.

Studies on the paleolimnology of acid susceptible lakes (Kejimikujik Lake, Nova Scotia) indicate organic soils and bogs have controlled the acidity of this lake. Diatom evidence indicates the pH trend has been to a lower pH. An increase in alkalinity is reflected by the diatom assemblage for the period 1850 to 1950 as a result of deforestation and burning of lumber refuse.

A sampler for use in measurement of toxic organics in precipitation was designed and tested.

The release of acidifying ions from the snowpacks is dependent on the amount of rain and the rate of snowmelt.

Microbiological studies of lakes receiving acid precipitation indicate that acidification of the lakes below pH 5.5 drastically affects microbial populations and organic matter degradation. Increased levels of organic matter in acid stressed lakes have been attributed to retarded microbial activity.

Three interlaboratory quality assurance studies for laboratories contributing data to the Long Range Transport of Airborne Pollutants Program have been completed. Some US laboratories are now participating in these studies.



## **CANADA-U.S. AND INTERJURISDICTIONAL WATER MANAGEMENT**

- An atlas of water chemistry data has been compiled with the aim of showing changes in Lake Ontario due to lake phosphorus management policies over the past 15 years. The spring concentration of soluble reactive phosphorus has decreased dramatically during the period of controls.
- A directory for the Global Environmental Monitoring System for water (GEMS/WATER) project which is part of the United Nations Environment Program was published. This directory contains the countries and laboratories that are participating in the project along with an inventory of the current station locations.
- A guide to the relationships between sediments and water quality was published in a form of a technical paper by UNESCO as a contribution to the International Hydrological Programme.
- A quality assurance program for the Prairie Provinces Water Board laboratories was initiated. Twelve interlaboratory comparison studies were compiled.

## DIRECTOR'S OFFICE

### SENIOR SCIENTIST

Dr. R.A. Vollenweider, the Senior Scientist of the National Water Research Institute, has continued to provide leadership in international activities. Sponsored by PAHO (Pan American Health Organization) he has visited Ecuador, Brazil, Colombia and Mexico, where he lectured in courses organized by countries and co-sponsored by CEPIS (Centro Panamericano de Ingeniería Científica y Ciencias del Ambiente, Peru). The objective of these courses was to familiarize sanitary and civil engineers, as well as university graduates, with the problem of eutrophication and water quality in lakes and reservoirs, and techniques of rehabilitation and prevention. Course attendance was normally between 25 and 50 participants from a majority of Latin American countries.

Further to this, he assisted CEPIS in developing a Latin American cooperative project on "Eutrophication in Warm Water Lakes and Reservoirs", and has advised national government institutions on lake and reservoir management (Poza Honda Reservoir, Ecuador; Lago Paranoa, Lago Santa Maria, Lago Descoberto, Brazil; Lago Tota, Colombia; Lago Chapala, Lago Cajititlan, Lago Zirahuen, Lago Patzcuaro, Lago Tequesquitengo, Mexico).

Further, Dr. Vollenweider has been invited by the Swedish Environment Protection Board as member of an international board to review and advise on eutrophication studies in the Baltic Sea, and by the Wahnbach Reservoir, Germany, authorities to advise on studies in that reservoir. He has assisted UNESCO on production of a Eutrophication Manual, and was chairman of a review workshop on "Results and Problems of the OECD Cooperative Programme on Eutrophication". He was also invited as discussion leader of the Closing Session of the conference on "Lake Léman Rehabilitation" at Geneva, co-sponsored by Switzerland and France, and as Session Chairman of the conference on "Chemical Processes in Lakes", Stans, Switzerland, organized by EAWAG, Dübendorf. He lectured at the University of Uppsala, the Swiss Federal Technical High School, and the Institute of Hydrobiology, Pallanza, Italian National Research Council. Also, he chaired the first and took part as a member of the second Inter-regional Review meeting for GEMS/WATER, under the responsibility of WHO, and contributed to the final reports.

In recognition of his international leadership in eutrophication studies and management, he has been given the Award of Excellence by the Rawson Academy of Aquatic Science, and has been proposed as a nominee for the Tyler Prize in Ecology.

### SCIENCE LIAISON OFFICE

This office was set up in August 1981 to assist the Director of NWRI in promoting the efficiency, effectiveness and relevancy of NWRI's Water Management Research. The office co-ordinates the Institute's multidisciplinary research program; participation in Environmental Impact Assessments, subventions programs, and committees; and public information.

The office was instrumental in the formulation and operation of a comprehensive Study Planning System. To facilitate research planning, the Institute is guided by a detailed Study Planning Manual and a computerized budget plan including information on national programs,

support services, external funding programs, shadow costs, and operational research needs. A system has been developed which solicits "research needs" from the operational components of Inland Waters Directorate to guide managers and scientists in planning their research activities. The system identifies Operational Contacts for research studies that are of direct interest to IWD Operational components. This is to formalize interaction among operational and research staff.

### HABITAT STUDIES

After a major absence of most stocks of lake trout from the Great Lakes during the past 30-40 years, due to the combined effects of over-fishing, lamprey predation and contaminants, there appear to be problems in achieving successful reproduction by hatchery stock introductions. The reasons for this are not clear but may relate to one or more of the following hypotheses: Habitat has been degraded, threshold trout densities have not been met, natural behavioural patterns are not yet properly re-established, it is too soon to tell what is responsible for the lack of natural reproduction.

Field observations in many parts of the Great Lakes, and inland lakes, indicate that active cobble-gravel beaches, coarse lag deposits, and talus slopes and irregular bedrock surfaces may all serve as spawning substrates. In most inland lakes, spawning takes place in shallow water (1-2 m); in the Great Lakes it may occur at depths as great as 30 m. Shallow water spawning occurs when fall temperatures drop to about 10°C. Deep water spawning is often below the thermocline and may occur in late summer (Lake Superior) or early fall (Seneca Lake).

Egg predation (particularly by fish and crustaceans) is high, during and immediately after spawning. Eggs, which fall into suitable substrates, swell and harden and become wedged between pebbles; during their incubation period they are very sensitive to movement and, therefore, further losses will occur if the substrate is not stable. Development during early stages of embryogenesis is easily disrupted by temperature shocks and by detrital accumulation. Embryo development is largely temperature controlled and, therefore, early hatches (shallow water) can be expected during short/warm winters, and late hatches following long/cold winters. Although egg-sac absorption provides a nutrient source for early stages of fry development, suitable forms of plankton must be available in sufficient concentrations to allow fry to complete the switch to exogenous feeding.

Substrates for deep water (sub-thermocline) spawning are not available in Lake Ontario, and studies of nearshore temperature data suggest that, because of rapid and extreme temperature changes during the fall overturn (Fig. 1), much of western Lake Ontario is frequently unsuitable for shallow fall spawning by lake trout (ripening is adversely affected by major temperature fluctuations). Temperature regimes are more suitable in the eastern part of the lake, and there is evidence that some natural reproduction by introduced stocks has occurred here. The numbers of observed spawning fish, however, are small and, therefore, the effects of predation are high. At sites where spawning has been observed, the fish appear to be using active (clean) cobble-gravel as a preferred spawning substrate. Because of the effects of fall storms and ice-movement it



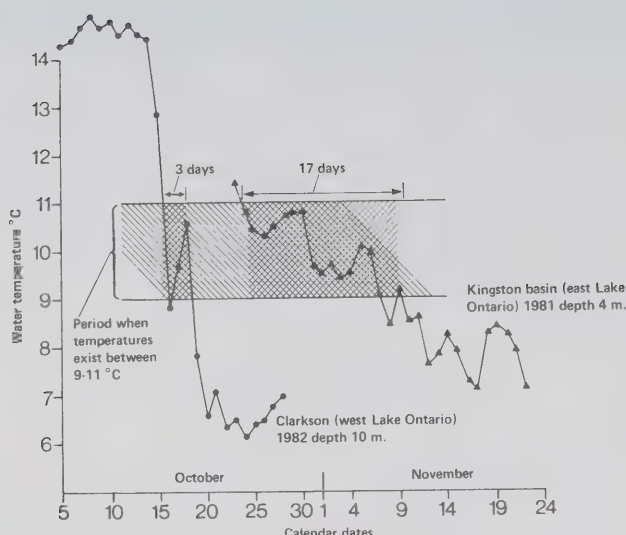


Figure 1 Lake Ontario temperature data showing extended period of 11-9°C water temperatures at the eastern end of the lake.

is likely that egg losses, during the incubation period, are high. Coarse substrates, at depths below wave disturbance, would seem to offer a better chance for egg survival but, because of the presence of aquatic weeds (often cladophora and milfoil), many sites, which formerly were used by lake trout (historical documentation), appear to have become degraded.

In Lake Ontario, therefore, it is probable that restoration of selected substrates and further improvements in near-shore water quality (and possible local weed removal) will increase the chances for successful reproduction by introduced stocks of lake trout.

## WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

In October 1974, the Canada Centre for Inland Waters was designated by the World Health Organization as its Collaborating Centre on Surface and Ground Water Quality (WHO/CC). The main function of the WHO/CC is (i) coordination of international technical assistance programs to the developing countries; and (ii) representation of Canada's freshwater interests in international forum.

In January 1976, the WHO/CC had initiated the publication of a quarterly journal *WATER QUALITY BULLETIN*, devoted to reviews of water management practices around the world. Furthermore, as of January 1977, the WHO/CC has assumed the responsibility of coordinating the establishment of a world-wide network of water quality monitoring stations on major rivers, lakes and aquifers around the world. The network is an integral component of the United Nations Global Environmental Monitoring System (GEMS). The main objective of this program is monitoring long-term trends in environmental pollution.

**GEMS/WATER.** By the end of 1983, over 200 000 data points had been reported by 435 monitoring stations located in 58 countries. To evaluate such data a group of international experts met at NWRI in July 1983. (Fig. 2) Its conclusions and recommendations are contained in a report entitled *GEMS/WATER Data Evaluation Report 1983*.



Figure 2 Participants at the GEMS/WATER Interregional Review Meeting at NWRI, October 17-21, 1983.

To review and act upon the recommendations of the group of experts, an Inter-Regional Review Meeting on Water Quality Monitoring Programs was held at NWRI in October 1983. The meeting, chaired by Dr. S. Barabas, was attended by official representatives of the six world regions and the participating U.N. agencies (WHO, UNEP and WMO).

The meeting agreed on the following:

- 1. Networks** — (i) to add more river baseline stations to the network, particularly from the dry and humid tropics; (ii) to broaden the representativity of the rivers discharging into the oceans by raising its coverage to about 54% of all rivers; and (iii) to broaden the representativity of the world's lakes by establishing monitoring stations in 23 additional major lakes and reservoirs.
- 2. Variables** — A revised list of water quality variables (formerly determinands) has been developed. The following variables have been dropped: MBAS, non-ionic tensides (detergents), Ni, Ba, Li, volatile suspended solids, total dissolved solids, Mirex, phytoplankton counts and volume, and primary production. The following variables have been added: TOC and Al in acidified waters. Only the following elements can be reported as both dissolved and total concentrations: As, Cd, Cr, Cu, Fe, Hg, Mn, Pb, Se, and Zn.
- 3. Study Projects** — The meeting agreed that the program can greatly benefit by undertaking additional studies which may include field work and/or synthesis of existing information on some problems previously identified. The following investigations have been suggested. (i) Review of the water quality-quantity relationships particularly in the wet and dry tropics in order to optimize the sampling frequency. (ii) Study of river sediments as a carrier of pollutants. (iii) Study of deposited sediments in lakes used as a record of water quality trends (e.g. for nutrients and trace metals(s)). (iv) Identification of algae which can release toxins in waters.

Other important problems have been identified but will not be considered in the program since they are or will be studied in other major projects. These are the effect of acid precipitation on freshwater resources, the contamination of groundwaters by refuse dumps, and the generation of toxic organics through chlorination.

- 4. AQC Training Course** — The first official GEMS/WATER Regional Training Course on analytical quality control (AQC) was held in Sao Paulo, Brazil during the period 2-13

May 1983. The course sponsored by WHO/PAHO and the Brazilian Government was hosted by the State of Sao Paulo Corporation CETESB. There were some 30 participants of which one half came from cities and towns from across Brazil and the other half from the following Latin American countries: Argentina, Chile, Colombia, Ecuador, Mexico, Peru and Uruguay. Dr. Barabas of the WHO/CC participated in the development of the course program and gave the introductory lecture at the course.

**WATER QUALITY BULLETIN.** Four quarterly issues of the Bulletin, in separate English and French editions, were published as scheduled. They were devoted to the following themes: (1) Water Around the World - Part 2; (2) Acid Precipitation - Part 1; (3) Acid Precipitation - Part 2; and (4) Wastewater and Hazardous Wastes Management. In all, 42 articles were published, written by 58 authors from the following 23 countries: Australia, Belgium, Canada, Denmark, Hungary, Italy, Japan, Kenya, Kuwait, Malaysia, Netherlands, New Zealand, Norway, Philippines, Poland, Rumania, South Africa, Sweden, Switzerland, United Kingdom, USA, USSR and Yugoslavia. The two issues of the Bulletin dealing with acid precipitation were particularly noted for their timeliness. It might be of added interest the increase in the number of pages published: from 196 pages in 1982 to 252 pages in 1983, or by over 28%.

**Foreign Visitors and Consultants Abroad.** During the year, study and discussion programs for 16 visitors from the following 12 countries were organized: Colombia, Egypt, France, Germany (FRG), India, Japan, Kenya, Peru, Switzerland, Tanzania, U.K., and U.S.A. Moreover, a water quality engineer from Tanzania was received at NWRI for a 2-month training period. Furthermore, several requests by WHO regional and national offices for Canadian consultants abroad were processed.

**Technical Assistance.** Inquiries received from around the world, particularly from the developing countries on different aspects of problems of water management, have been responded to.

## STAFF LIST

**Director — Dr. G. Keith Rodgers**  
**Secretary — Mrs. M. Stapleton**  
**Receptionist — Mrs. D. Burford**

Science Liaison Officer                      Mr. D.A. Bondy

Senior Scientist                                Dr. R.A. Vollenweider  
 Assistant                                        Miss L. Janus

World Health Organization/CC/SGWQ  
 Manager                                        Dr. S. Barabas  
 Secretary                                        Mrs. N.J. Clegg

Glenora Fisheries Research Station  
 Scientist                                        Dr. P.G. Sly  
 Secretary                                        Mrs. M. Stephen

## COMMITTEE MEMBERSHIP

Dr. G.K. Rodgers

International Joint Commission Science  
 Advisory Board

IWD Research Subventions Committee

Water Research Advisory Committee

Canada-Ontario Rideau Trent System  
 (CORTS)

Dr. R.A. Vollenweider

Senior Scientific Advisory Panel on  
 Eutrophication (UNESCO) — Chairman

Subcommittee on Water, National Research  
 Council, Associate Committee on Scientific  
 Criteria for Environmental Research

Departmental Committee for the  
 Scientific Research Group

Advisor to CEPIS/PAHO, Lima, Peru on  
 "Latin American Cooperative Programme on  
 Eutrophication in Warm Water Lakes and  
 Reservoirs"

Fellow, Rawson Academy

Editorial Board of "Memorie dell'Istituto  
 Italiano di Idrobiologia", Verbania-Pallanza,  
 Italy

Editorial Board, WHO "Water Quality  
 Bulletin"

Review Board, GEMS/WATER Data  
 Evaluation — Chairman

Scientific Advisory Committee "Cervia  
 Ambiente", Italy

Advisory board, Expert Group on Marine  
 Eutrophication, to the Research Committee  
 of the National Swedish Environment  
 Protection Board

Dr. P.G. Sly

Editorial Board, "Canadian Research"

Editorial Board, "Canadian Geotechnical  
 Journal"

International Association Great Lakes  
 Research — President

Lake Ontario Working Group, Great Lakes  
 Fisheries Commission

Committee on Lake Trout Research, Great  
 Lakes Fisheries Commission



## PUBLICATIONS

- Barabas, S.** 1983. GEMS/WATER — A Program of Global Water Quality Monitoring. Impact of Science on Society, No. 1, p. 105-115. (GEMS/EAU. SURVEILLANCE DE LA QUALITE DE L'EAU, Impact: Science et Société, no. 1, p. 115-125.)
- Barabas, S.** 1983. The Water Decade — One of the Noblest and Most Ambitious United Nations Projects. An invited lecture given at the Annual Dinner Meeting of the United Nations Association, Hamilton District Branch. CCIW Unpublished Manuscript, 23 pp.
- Barabas, S.** 1984. Canada's Leading Role in Implementing the United Nations Program on Water Quality Monitoring. Can. Journ. of Public Health, 75:69-73.
- Janus, L.L. and R.A. Vollenweider** 1983. Phosphorus Residence Time in Relation to Trophic Conditions in Lakes. Verh. Internat. Verein. Limnol., (In press).
- Sly, P.G.** 1983. Sedimentology and geochemistry of recent sediments off the mouth of the Niagara River, Lake Ontario. Jour. Great Lakes Res., 9: 134-159.
- Sly, P.G.** 1983. Recent sediment stratigraphy and geotechnical characteristics of foreset and bottomset beds of the Niagara Bar. Jour. Great Lakes Res., 9: 224-233.
- Sly, P.G., R.L. Thomas and B.R. Pelletier** 1983. Interpretation of moment measures derived from water-lain sediments. Sedimentology, 30: 219-233.
- Sly, P.G. and R.G. Sandilands** 1983. Side scan sonar survey and study of red and white targets in Lake Ontario — 1978 (Hamilton and Scourge). NWRI Unpublished Manuscript, 35 p.
- Sly, P.G.** 1983. Biological considerations for open water disposal of dredged material in the Great Lakes. Inland Waters Branch Scientific Publications Series.
- Sly, P.G.** 1983. Sedimentology and geochemistry of modern sediments in the Kingston Basin of Lake Ontario. Journ Great Lakes Res. (In press).
- Sly, P.F. and Wyn-J. Prior** 1983. Late glacial and post glacial geology in the Lake Ontario Basin. Can. Jour. Earth Sci. (In press).
- Sly, P.G. and C.P. Schneider** 1983. The significance of seasonal changes on a modern cobble-gravel beach used by spawning lake trout, Lake Ontario. Jour. Great Lakes Res. (In press).
- Sly, P.G. and C.C. Widmer** 1983. Lake Trout (*Salvelinus namaycush*) spawning habitat in Seneca Lake, New York. Jour. Great Lakes Res. (In press).
- Sly, P.G.** 1983. Historical changes in the Bay of Quinte. Can. Jour. Fish. Aquat. Sci. (In press).
- Sly, P.G., and R.G. Sandilands** 1983. Sediment distributions in an area of the submerged Niagara Escarpment, Georgian Bay. Jour. Great Lakes Res. (In press).
- Vollenweider, R.A.** 1983. Notion de Charge Admissible. Proc. Conference on Eutrophication and Pollution of Lake Geneva, Geneva, Switzerland, (In press).
- Vollenweider, R.A.** 1983. Review and Critical Assessment of the OECD International Cooperative Programme on Eutrophication. Verh. Internat. Verein. Limnol. (In press).
- Vollenweider, R.A.** 1983. Water Quality Aspects of Lakes/Reservoirs: Criteria for Assessing Lakes/Reservoirs in Terms of Representativity, Pollution Sensitivity and Potential Pollution Occurrence. GEMS/WATER Data Evaluation. Unpublished Report.
- Vollenweider, R.A.** 1983. Report on PAHO Project ECU-2000, re Eutrophication of Lakes and Reservoirs. Quito, Ecuador. Unpublished report.
- Vollenweider, R.A.** 1983. Report on PAHO Project COL-2320, re Lake Tota, Colombia. Unpublished report.
- Vollenweider, R.A.** 1983. Report on PAHO Project MEX-6400, re Management and Conservation of Lakes, Guadalajara, Mexico. Unpublished report.

## AQUATIC ECOLOGY DIVISION

The Aquatic Ecology Division is involved in the solution of the problems associated with environmental degradation of Canadian waters due to eutrophication, acidification, and infestation by aquatic weeds, with the objective to contribute to the management of their quality.

The Aquatic Ecology Division is organized in three multidisciplinary sections: Ecological Impact, Great Lakes Rehabilitation, and Nutrient Pathways.

### ECOLOGICAL IMPACT SECTION

The major area of research of the Ecological Impact Section has been related to acidification of lakes with emphasis upon the long-range transport of atmospheric pollutants. Studies have emphasized sulfur isotopes as tracers of acid rain; metal deposition from such sources as mining and smelting activities at Sudbury and Atikokan, Ontario and Rouyn-Noranda, Quebec; the use of diatoms as indicators of the acidification history of lakes and the impact of acidification on the carbon cycle in lake sediments. Other areas of research by section members include the impact of peat mining upon aquatic ecosystems; the application of statistical methodology to limnological problems; organic geochemistry of Great Lakes sediments; indicators of climatic change, and impacts of coal-fired power plants on the environment.

**Acid Rain Studies.** Analysis of sediments and suspended particulates from a number of lakes in the area of Sudbury are being carried out to determine the degree to which they record ecological changes. Naturally occurring hydrocarbons, fatty acids, alcohols and sterols (geolipids) were found to be conservative with respect to organic carbon. Thus, distribution changes for the geolipids in the sediments may be used to indicate environmental changes in the lakes. Organic carbon and geolipid contents from surficial sediments of ten lakes correlated inversely with pH. These results are consistent with studies which show decreased microbial activity in lakes of lower pH. Detailed GC and GC/MS analyses are underway which will give more specific information on ecological changes and on the cycling of organic matter in these lakes. (*Bourbonniere*)

The present-day and historical inputs of heavy metals into the lakes of the Algonquin Provincial Park areas of Ontario have been assessed. Lake water, particulate matter and sediment cores were collected in this area and analyzed for Pb, Zn, Cu, Ni, Cd and other trace pollutants.

The sedimentary profiles for Pb, Zn and Ni demonstrate the impact of atmospheric input as a result of long-range transport of materials. There has been rapid increase in Pb burdens of the atmosphere in the past 50 years and the sedimentary record in these remote lakes documents the great intensity of Pb input into the park ecosystem. The Zn profile clearly indicates a 2-fold enrichment in the surficial sediments compared to the precolonial levels. Also, similar Zn profiles are observed in the Adirondack and New England Lakes confirming that the introduction of Zn is a regional atmospheric phenomenon. The precolonial concentration of Ni in the Algonquin Lake sediments is close to the crustal abundance, compared to approximately a 2-fold enrichment of Ni in the surficial sediments. With only 90-120 km separating the Sudbury smelter stacks and the Algonquin Lakes, the possibility that most of the excess Ni is derived from Sudbury cannot be discounted.

Metal flux rates from sediment trap experiments were observed to increase with water depth. Large difference in flux between surface and bottom traps are most likely to be caused by resuspension of bottom sediments. Metal flux rates from May to June were 0.9-2.6, 0.8-3.2, 4.0-12.2, 5.5-36.0 and 3.5-24.0  $\text{mgM}^{-2} \text{day}^{-1}$  ( $\times 10^2$ ) for Cu, Ni, Pb, Zn and Fe respectively. A comparison of spring and summer particulate metal fluxes with annual values from recent sediments (Pb-210 dated) and the estimated atmospheric input suggest that a major portion of the pollutant metals is being transported, exported and deposited during the warmer months when the lakes are not ice covered. (*Wong & Nriagu*)

Variations in sulfur isotopes and in the Se/S ratios have been used to study the sources, dispersion pathways and ultimate sinks for the two elements in lakes of northern Ontario. The data obtained suggest that sulfur is relatively immobile in sediments and that the accumulation of excess sulfur reflects the increasing input of pollutant sulfur into the lakes. This implies that sulfur and selenium in sediments represent potential tracers for recent changes in the composition and acidity of rainfalls in northern Ontario. (*Nriagu*).

Studies continued on the paleolimnology of acid susceptible lakes. Results from Kejimikujik Lake, Nova Scotia, indicate organic soils and bogs have controlled the acidity of this lake. Diatom evidence indicates the pH trend has been to a lower pH. An increase in alkalinity is reflected by the diatom assemblage for the period 1850 to 1950 as a result of deforestation and burning of lumber refuse. Results from the headwater lake (Batchawanna) part of the Turkey Lakes system indicate several diatom species which are acidiphilous or acidobiontic. Species such as *Tabellaria flocculosa*, *Surirella delicatissima*, *Eunotia flexuosa*, and *Actinella punctata* are tolerant of low pH. The establishment of a beaver dam around 1400 A.D. had the effect of altering the floral assemblage as indicated by the presence of *Nitzschia amphibia*. (*Delorme*)

**Peatlands Development and Conservation.** The use of peat combustion for energy production is receiving renewed interest. Large power plants, up to 600 MW, exist in Finland and the U.S.S.R., while smaller scale operations occur elsewhere.

Canada is estimated to have the largest peatland acreage in the world,  $170 \times 10^6$  ha. The major Canadian peat reserves are found in Ontario with an estimated  $26 \times 10^6$  ha;  $9.9 \times 10^6$  ha occurs south of the permafrost line.

Since peat needs a water content of 50-55% for combustion, one tonne of peat dried to this moisture content would release four tonnes of water to nearby aquatic ecosystems. Two major areas of environmental concern are apparent: (1) the impact of peat "mining", and (2) the impact of peat combustion.

Peat extraction, using conventional technology, requires drainage of peatlands followed by dewatering. In general, such discharge waters are low in pH, high in colour, aluminum, mercury, nitrogen, and phosphorus, i.e. similar in composition to lakes subjected to acid rain problems. There also has been some observations that water discharging from exploited peatlands has impaired fish spawning, both in the U.S. and Nova Scotia (salmon). As for combustion, peat is similar in potentially toxic metal concentration to coal, but sulfur is lower.



In 1983, studies began on the potential impact of such drainage waters upon receiving water bodies including lakes and streams. Sampling occurred in Nova Scotia, Quebec and Ontario to obtain peat and drainage water from contrasting sites. Initial work on organic compounds includes isolation of hydrophobic and hydrophilic acids. Naturally occurring constituents of bog plants are being surveyed to aid in determining sources of organics found in peat and drainage water. (Glooschenko, Bourbonniere)

**Atmospheric Transport of Pollutants.** Mining and smelting activities can result in the atmospheric transport and deposition of potentially toxic elements such as metals, arsenic, and selenium. Monitoring of deposition of these substances can be done by analysis of lower vegetation collected at various distances from sources.

At the present time, a coal-fired electrical generating station is under construction at Atikokan which is scheduled to go on line in the winter of 1984. A baseline study has begun in which replicate samples of *Sphagnum fuscum* moss and leaves of the low shrub *Chamaedaphne calyculata* have been collected from 5 bog sites. In addition, forest floor litter was collected at two sites. These have been analyzed for potentially toxic metals and sulfur. The same sites will be resampled for several years after the plant begins operation to determine if the plant significantly increases atmospheric metal deposition in the area. (Glooschenko)

*Sphagnum* moss was also collected at varying distances from two iron-mining and processing centres in northern Ontario — Atikokan and Sudbury — and analyzed for Fe. All samples were collected in ombrotrophic bogs which receive chemical inputs strictly from atmospheric deposition.

Mosses from the Atikokan area had elevated concentrations of Fe up to 7352 mg kg<sup>-1</sup>. Atikokan, a mining and ore-processing centre caused elevated Fe levels up to 50 km distance from the town, while Sudbury exhibited a greater influence due to the tall stack there. At Sudbury, levels ranged from 2478 mg kg<sup>-1</sup> near the town to 382 mg kg<sup>-1</sup> in remote sites. Results from these moss analyses were similar to those obtained from direct precipitation sampling of other authors. (Glooschenko)

The Noranda copper smelter in Rouyn-Noranda, Quebec is a major source of SO<sub>2</sub>. Heavy metals and other elements occur in sulfide ores which when smelted, emit large amounts of heavy metals associated with the ores into the atmosphere. A study was made to assess metal distributions due to atmospheric deposition, and runoff from mine tailings on lakes in the area. Sediment cores were collected from lakes in the study area for metal analysis. Enrichment factors were calculated for lake sediments (Fig. 1). Such cores exhibited high metal loadings in the top 7 cm of sediment of Cu, Zn, Fe, Pb and Mn in lakes near the smelter, lower levels were found in lakes further away within a 70 km radius. Metal loadings were attributed to a variety of sources including mine tailings, land runoff, and aerial deposition. Enrichment factors for heavy metals, when compared with those of Lake Erie, were greater and varied from 10X to 500X, particularly for Cu, Fe, Zn and Cd. The surface water analysis from lakes within 10 km radius exhibited high sulfate, calcium, magnesium and sodium when compared with other regional lakes. The elevation in calcium may be attributed to the liming of mine tailing ponds in the area with subsequent lake water contamination through spring runoff or streams. (Arafat)

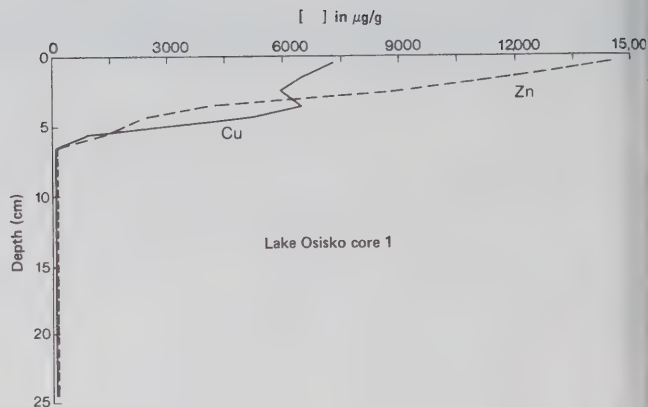


Figure 1 Distribution of zinc and copper with depth in a core from Lake Osisko at Rouyn-Noranda. Note enrichment of these elements at 6 cm depth corresponding to beginning of smelter operation.

## GREAT LAKES REHABILITATION SECTION

The Great Lakes Rehabilitation Section continued research on topics related to the Canada-U.S. Agreement on Great Lakes Water Quality. These topics included the chemical and biological response to lake management, the movement of nutrients and contaminants, the distribution of bottom dwelling organisms, the storage mechanism of nutrients in sediment and the distribution of aquatic macrophytes in response to nutrient loading.

**Lake Erie.** Eutrophication in Lake Erie has been one of the dominant themes of the research of the Great Lakes Rehabilitation Section. New technologies have been used to monitor the response of summertime oxygen depletion to nutrient loading reduction. Development and construction of oxygen profiling equipment began in 1980 and has resulted in the use of a prototype system in surveys of Lake Erie during 1983. The new equipment uses electronic sensors and a microcomputer to control the lowering winch, interpret the signals, and record the data on diskettes. In addition to reducing labor costs and reducing transcription errors, the profiler reveals details of oxygen/temperature stratification which could not be sampled adequately with previous bottle techniques. The oxygen profiles are displayed on the screen of the microcomputer as the sensor is lowered and are later printed so a hard copy of the information is produced instantly (Fig. 2). (Charlton)

Total phosphorus loading to Lake Erie has been decreasing since 1968. To determine how the lake concentrations responded to loading decreases, survey data from 1968 to 1981 were plotted to show concentration changes in the Central Basin (Fig. 3). The total phosphorus concentrations for the uppermost layer under stratified conditions and otherwise, for the whole water column were averaged for each station in the Central Basin during the whole year. The loadings decreased by 1170 ± 130 tonnes yr<sup>-1</sup>, while the lake concentrations decreased at a rate of 0.57 ± 0.11 mg·m<sup>-3</sup>·yr<sup>-1</sup>, from 1968 to 1981. This means that for every 1000 tonnes of phosphorus removed from annual loadings, the concentrations in the lake decreased by approximately 0.5 mg·m<sup>-3</sup>. (Rosa)

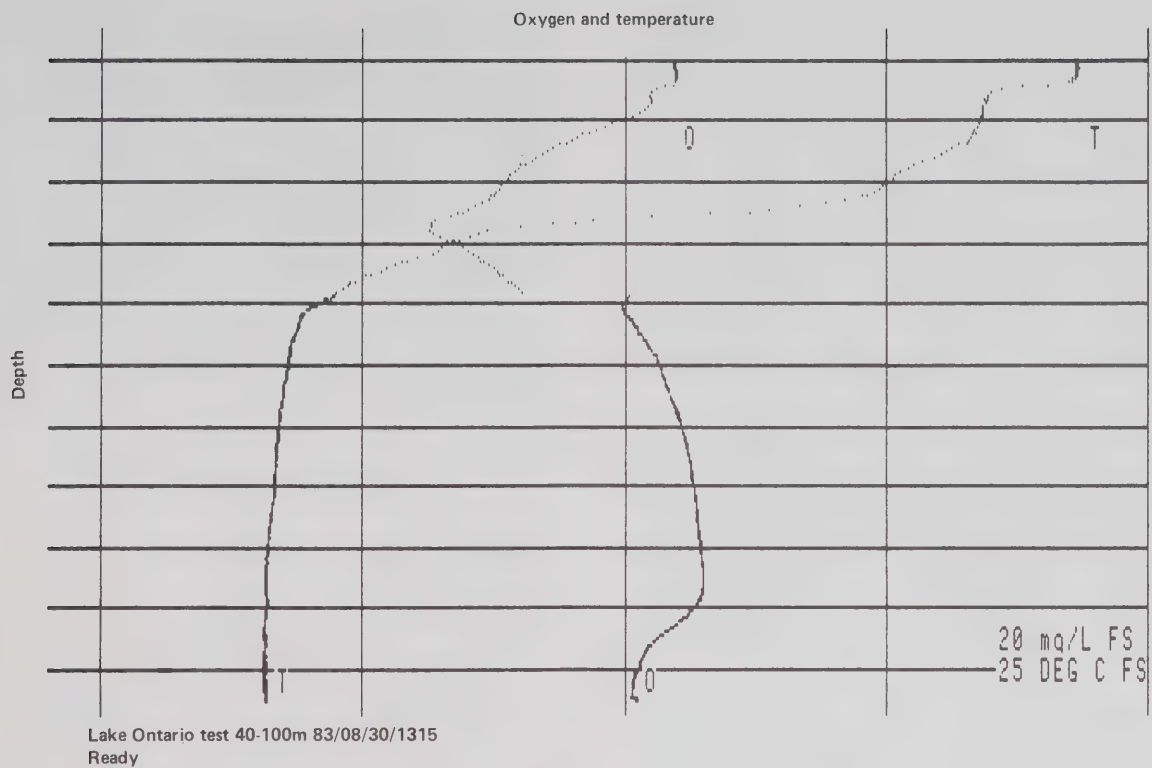


Figure 2 Oxygen and temperature profiles measured with a digital oxygen profiler.

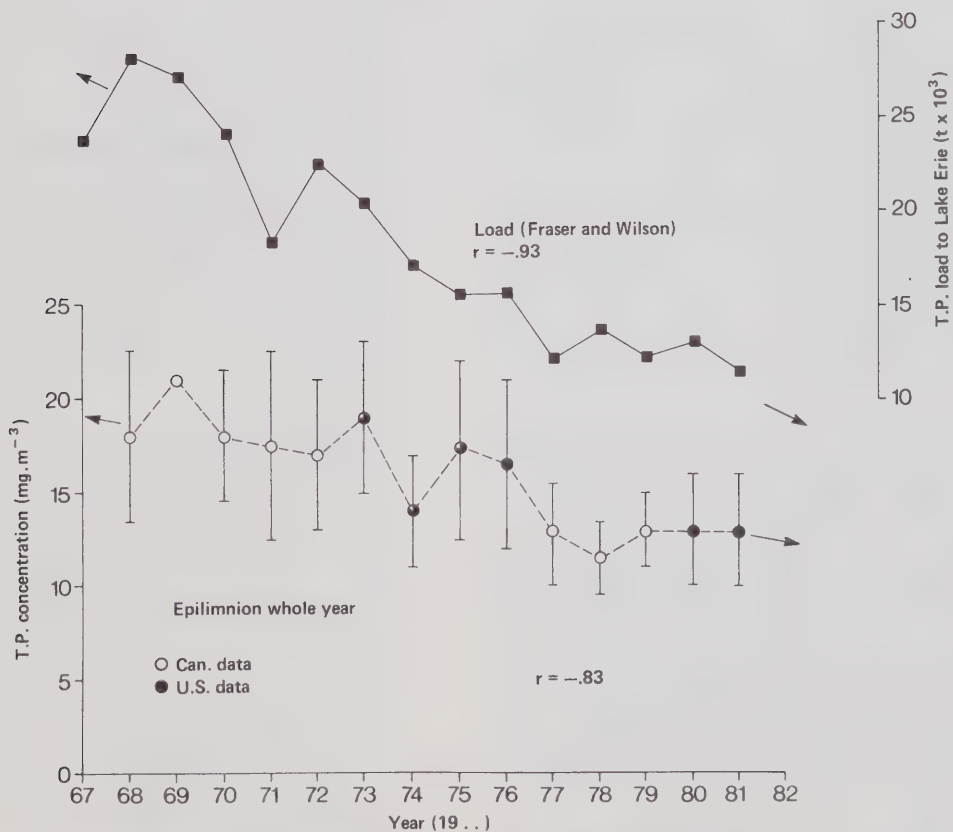


Figure 3 Lake Erie, central basin changes in phosphorus loadings and open lake phosphorus concentrations during the last 15 years. Arrows indicate the ends of trend lines through the data.



**Water Quality Trends.** The water chemistry of the Great Lakes has been monitored for the past 15 years. The purpose of the monitoring has been to detect any unacceptable conditions and to follow the response of the lakes to environmental controls imposed in the early 1970s. Due to phosphorus controls at sewage plants, the concentration of soluble reactive phosphorus was expected to decrease in the lakes. An atlas of water chemistry data has been compiled with the aim of showing changes in Lake Ontario due to lake management policies. The spring concentration of soluble reactive phosphorus has decreased dramatically during the period of controls. The Atlas also revealed seasonal cycles of water chemistry parameters and time-depth diagrams of the concentration of biological indicators such as chlorophyll. (Dobson)

The movement of particles carrying nutrients and contaminants was studied with sediment traps in Lake Ontario. These studies resulted in three reports on the movements of material loaded from the Niagara River and resuspended from the bottom of Lake Ontario. The study of the fate of Niagara River inputs was extended to the whole lake area in 1983. Results indicate that there is much resuspension of bottom sediments which may enhance the availability of nutrients and contaminants in the lake. (Charlton, Rosa)

**Phosphorus Availability.** Phosphorus storage in lake sediments delays the response of lakes to increases and decreases in phosphorus loading. Knowledge of the exact form of phosphorus which is both regenerated from sediments and absorbed by algae is important to understanding lake response to management actions. Most of the phosphorus in sediment entering lakes is in the form of "apatite" which is not available for algal growth. The non-apatite inorganic phosphorus (NAIP) fraction contains bioavailable forms and these are being investigated by chemical extraction and Mossbauer spectroscopy methods. Chemical extraction reveals the amount of NAIP while spectroscopy provides information on the type of iron-phosphorus compounds which comprise NAIP. The combination of the two methods shows that sediment NAIP is largely related to oxygen sensitive iron (Eh-sensitive  $\text{Fe}^{3+}$ ) with a background portion related to other chemically resistant iron compounds. The oxygen sensitive iron-phosphorus compound is likely phosphate-iron-hydroxide. Another widely used way to estimate bioavailable phosphorus is with O.I.M. NaOH. NaOH-extractable phosphorus does not correlate as well as NAIP to Eh-sensitive  $\text{Fe}^{3+}$ . (Manning)

**Aquatic Weeds.** Eurasian watermilfoil (*Myriophyllum spicatum*) is a nuisance aquatic plant currently infesting many recreational lakes in Canada. Environment Canada's research has concentrated on assessing the long-term impact of harvesting on milfoil regrowth and attempting to determine the mechanism behind the decline of milfoil in several lakes in Ontario. A harvesting experiment is in its third year and the growth in the harvested plot has been reduced to a quarter of the control area. Laboratory experiments have indicated that the high sediment levels of hydrogen sulfide and ammonium and low levels of iron are not responsible for a decline in milfoil biomass which has been observed in several lakes in Ontario in recent years. A further experiment is necessary to test the effect of low sediment porewater phosphorus. (Painter)

*Cladophora* research is now concentrated on examining the nearshore environmental conditions along the north shore of Lake Ontario that affect *Cladophora* growth. A

computer simulation model was used to assess the growth potential of various sites. The model inputs are temperature, turbidity, and phosphorus and the outputs are tissue phosphorus, phosphorus uptake, net and gross photosynthesis and biomass. The model will be used to evaluate the importance of local nutrient inputs compared to the nutrient supply in open lake water. Figure 4 illustrates a typical output from the model. The inputs were temperature, turbidity and phosphorus for the 1981 summer at Port Credit. The model output is the seasonal phosphorus uptake and tissue phosphorus concentration of *Cladophora*. Tissue phosphorus concentrations above 0.13% are widely believed to be optimum for growth. Therefore, the Port Credit area appears to be ideal for *Cladophora* growth. (Painter, Charlton)

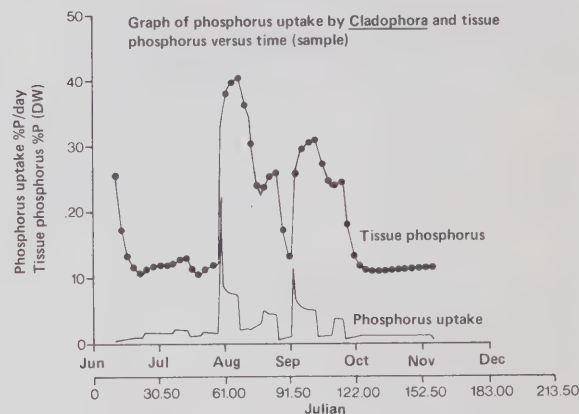


Figure 4 Changes in phosphorus uptake and tissue phosphorus of *Cladophora* predicted by computer model for a site at Port Credit, Lake Ontario.

## NUTRIENT PATHWAYS SECTION

The Nutrient Pathways Section continued to concentrate on understanding the complex interrelated processes of nutrient availability (or limitation), algal growth (and biomass), nutrient regeneration, dissolved organic substances (their presence and defining their roles in the environment), zooplankton grazing, and lake restoration methods.

**Microbiology.** Chroococcoid cyanobacteria (0.7-1.3  $\mu\text{m}$  diameter) were discovered to be a significant component of the Lake Ontario plankton. Using epifluorescent microscopy, the densities of these microorganisms were found to vary by 4 orders of magnitude with a single large abundance peak ( $6.5 \times 10^5$  cells  $\text{mL}^{-1}$ ) corresponding to the time of maximum water temperature ( $15^\circ\text{C}$ ). Figure 5 illustrates this seasonal pattern and how the organisms are correlated to temperature. The Chroococcoid cyanobacteria constituted 10% of the bacterial numbers in the epilimnion during its peak abundance, approximately 40% of the biomass of prokaryotes  $2.0 \mu\text{m}$ , and 30% of the biomass of all microorganisms  $20 \mu\text{m}$  in size. Cyanobacteria observed in the food vacuoles of heterotrophic microflagellates and in the guts of rotifers suggest that these organisms may be important consumers of this prokaryotic population. (Lean).

In a combined AED-AMD project, the effect of low pH stress (acid rain stress) on lake bacteria was shown to in

volve both physiological and structural adjustments by the bacteria. The bacteria in lakes with decreasing pH levels (pH 7 to pH 4), showed progressive changes in (1) their surface structure, (2) their respiration rate, and (3) their physiological capacity to decompose organic substrates. Exposing a pure lakewater bacterial culture to increasing pH levels, we discovered that the bacterial surface structure could be used as an indicator of acid stress levels. By photographing a high-resolution electron microscopic image of the surface of a stressed bacterial cell, one can record diagnostic structural features which indicate the external pH. (Leppard)

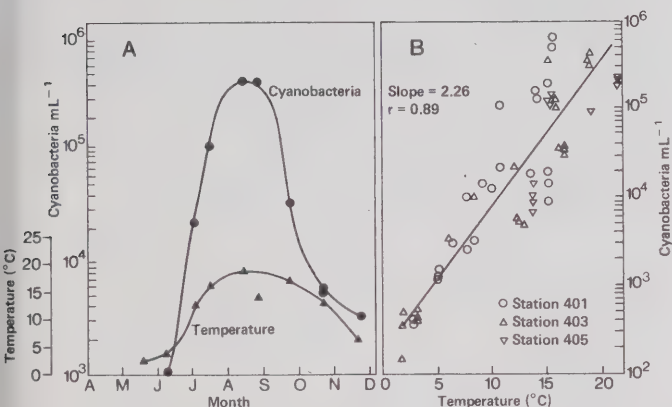


Figure 5 Chroococcoid cyanobacteria in Lake Ontario. (A) Seasonal pattern in 1982. (B) Correlation of Chroococcoid cyanobacterial abundance at all tested stations as a function of temperature.

**Internal Nutrient Loading.** After the phosphorus loading to lakes is reduced, there is sometimes a delay in the predicted rate of improvement which is caused by internal loading of phosphate from the sediments. The extensive literature on the influence of oxygen in forming a redox boundary at the sediment water interface suggests that, in the presence of oxygen, iron compounds would reduce internal loading. Throughout the world there have been a number of experiments where oxygen or air has been added to the hypolimnion in the hope that internal loading would be reduced and iron compounds in the anaerobic water would precipitate the soluble phosphate making it biologically unavailable. Unfortunately, the success rate in lake restoration using this technique has been only about 60%. In a carefully controlled experiment at Lake St. George, the explanation for the low success rate was discovered. In lake sediments where hydrogen sulfide is produced, all the iron available for phosphate complexation is permanently immobilized. Aeration under these conditions has little effect. Only by the addition of iron will aeration provide the reduction of algal biomass.

In an attempt to measure internal loading rates from lake sediments, pore water peepers were positioned in the muds of Jacks Lake. Using these diffusion chambers, the diffusion rates for many substances can be determined (phosphate, iron, manganese, carbon dioxide, methane, hydrogen sulfide, ammonium, etc.). Concentration profiles for  $\text{PO}_4^{3-}$  are shown for several water depths in Figure 6. In the one basin  $\text{PO}_4^{3-}$  input rates varied considerably with depth but the predicted rate, from diffusion calculations, was close to the actual measured input from the hypolimnion. Internal loading was found to be the major mechanism which influences the vertical stratification of elements during summer stratification. (Carignan, Lean)

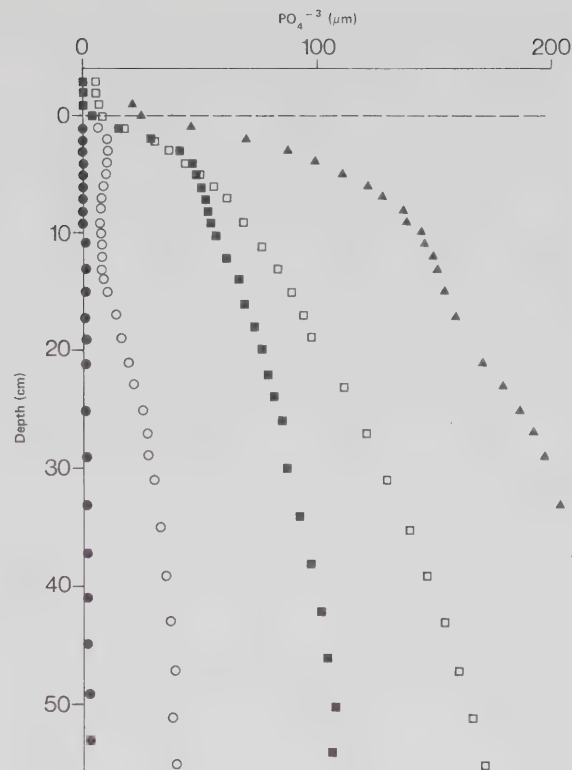


Figure 6 Concentration profiles  $\text{PO}_4^{3-}$  in Jacks Lake sediments at various water depths. 4m (●), 10m (○), 15m (■), 18m (□), 21m (▲).

**Nutrient Manipulation.** The weathering of phosphate minerals and cattle feedlots are both uncontrollable sources of nutrients in the south central interior of British Columbia. In several sites the eutrophication of lakes results in fish kills and large algal blooms. We resolved to determine why some lake restoration projects in the dry interior of British Columbia are unsuccessful, and to develop a new lake restoration technique, lime addition. Our studies were done in collaboration with the B.C. Fish and Wildlife Branch and the Pacific and Yukon detachment of NWRI. We have confirmed our earlier observations that carbonate lakes have too little reactive iron for lake aeration to precipitate ferric phosphate. In carbonate lakes, lake aeration probably cannot precipitate phosphate. We have observed in several hardwater lakes a highly variable amount of phosphate coprecipitation with calcium carbonate. We enhanced this natural reaction in one naturally eutrophic lake with 23 tonnes of lime. The lime application to Frisken Lake removed 97% of the phosphate and 80% of the chlorophyll a from the epilimnion. In the hypolimnion, the decomposition of the algae reduced the pH and much of the precipitated phosphate-carbonate complex redissolved. *Daphnia* were not killed by the lime, and they appeared to move into a zone of intense heterotrophic activity in the hypolimnion. When the top of the hypolimnion mixed with the alkaline epilimnion, 50% of the phosphate in the lake precipitated to the sediments. Because the initial mixing had consumed the excess alkalinity, further mixing of the hypolimnion had no effect on phosphate solubility. (Murphy)

In collaboration with DFO-Freshwater Institute, Winnipeg, field experiments with snow clearing on Rock Lake, Manitoba were completed and the feasibility of using this method to improve dissolved oxygen conditions was



evaluated. Verification of previously proposed summerkill and winterkill predictive models was also finalized. (*Barica*)

**Bioavailability.** One of the Section's mandates is to study the bioavailability of phosphorus. The main reason why this is so important is because we cannot accurately measure the concentration of orthophosphate in lakewater. Limnologists have to resort to terms such as soluble reactive phosphorus (SRP) to identify the fraction of the phosphorus in lakewater which is measured by the standard chemical test (Murphy-Riley procedure). However, the SRP value may or may not be accurate. Often the SRP is 10-100 times higher than a value determined by a non-routine radiobioassay. Many researchers have felt that undescribed phosphorus-containing compounds would hydrolyse under the acidic conditions used to measure SRP. An attempt was made to resolve this controversy by labelling lakewater compartments with radioactive orthophosphate. Gel chromatography was used as a monitoring aid to determine what happened to the radioactive colloidal phosphorus compound when subjected to the Murphy-Riley procedure. No hydrolysis to orthophosphate was detected. The reason behind the discrepancy still is unknown and illustrates the need for an accurate method for phosphorus bioavailability. (*Burnison*)

*Cladophora* is a nuisance filamentous algae causing problems in nearshore areas of the Great Lakes. We demonstrated that the beaching and subsequent decay of *Cladophora* in the Hamilton to Oakville area of Lake Ontario coincided with a recent taste and odor event in the local water supply. We studied this problem in cooperation with Halton Region. Water samples from the Burlington water treatment plant (WTP) and from shoreline areas were analyzed for geosmin and methylisoborneol, two frequently reported compounds associated with taste and odor problems in water supplies. Geosmin was identified in some of the finished water from the WTP. Methylisoborneol was not detected in any of the samples. The source of the geosmin is not clear at this point. There is some indication that the lakewater is one source; but since the finished WTP water had higher concentrations than the raw water, the WTP may have produced geosmin. Other volatile compounds are present in the lakewater which have offensive odors. For example, during a massive dieoff of *Cladophora*, methylindole and elemental sulfur were produced. Two other compounds were tentatively identified as dimethyl tetrasulfide and dimethyl pentasulfide. (Brownlee, Painter)

## STAFF LIST

Chief — Dr. J.M. Barica  
Secretary — Ms. J. Major  
Administrative Officer — Mr. F. Boyd

## Nutrient Pathways Section

Head,  
Dr. B.K. Burnison

## Researchers

Mrs. A. Abbott      phosphorus kinetic studies and  
data analysis

Dr. B.G. Brownlee      aquatic chemistry, nutrients

Dr. D.R.S. Lean      ecosystem engineering,  
phytoplankton physiology

Dr. G.G. Leppard      aquatic biophysics, ultra-  
structure of lake colloids

Mr. T.P. Murphy limnology, nutrients

### Visiting Scientist

Dr. H.J. Fricker      zooplankton grazing,  
size fractionation

### Technical Staff

Mrs. K. Edmonson  
Ms. G.A. MacInnis  
Mrs. D.J. Nuttley  
Ms. D. Urciuoli

## Volunteers

Kathleen Kemp  
Sylvia Soder

## Great Lakes Rehabilitation Section

Head, lake productivity, oxygen  
Mr. M. N. Charlton sedimentation

## Researchers

Dr. L.L. Kalas	benthic ecology
Dr. P.G. Manning	sediment-water interactions
Mr. D.S. Painter	Aquatic Ecology
Mr. F. Rosa	oxygen, particle settling, re-suspension, Lake Erie

### Visiting Scientist

Mrs. G. Zimmermann      lake sediment calorimetry

### Technical Staff

Mr. W.G. Booth  
Mr. H.F.H. Dobson  
Mrs. T. Mayer  
Ms. J. Wood

## Volunteers

Mr. David Oliver  
Miss Ruth Robertson  
Dr. Dick Buggeln  
Mr. Ron Boone  
Ms. Pat Moskal

## Ecology Impact Section

Head,  
Dr. W.A. Glooschenko wetlands ecology, sediment  
geochemistry, peat impact

## Researchers

Dr. R.A. Bourbonniere	organic geochemistry
Dr. L.D. Delorme	paleolimnology
Dr. S.R. Esterby	applied statistics, specialization in limnology and ecology

Dr. J.O. Nriagu      geochemistry, cycling of trace  
metals and sulfur in aquatic  
ecosystems

Mr. H.K.T. Wong      geochemistry, geochronology

## Post Doctoral Fellow

Dr. Y.K. Soon      soil chemist,  
nutrient cycling

### Technical Staff

Mr. N. Arafat  
Mr. R. Coker  
Ms. N. Harper

## COMMITTEE MEMBERSHIP

- J. Barica**  
 Editorial Board, "Water Pollution Research Journal of Canada"  
 Great Lakes Working Group, Eutrophication Issue Group  
 Plains Aquatic Research Group, Executive Committee  
 Symposia Group, Canadian Committee IAWPRC  
 Editorial Board, WHO "Water Quality Bulletin"

- R.A. Bourbonniere**  
 Peat Environmental Committee

- B.K. Burnison**  
 CCIW Radionuclide Control Committee  
 Editorial Board, WHO "Water Quality Bulletin"

- M.N. Charlton**  
 Lake Erie Surveillance Task Force  
 Lake Superior Surveillance Task Force

- L.D. Delorme**  
 International Union for the Conservation of Nature  
 IUCN Survival Service Commission  
 Canadian Committee on Climatic Fluctuations and Man  
 Task Force on Proxy Data  
 Atmospheric Environment Service, IWD Contact Person for the Carbon Dioxide Committee

- S.R. Esterby**  
 ASTM Biometrics Sub-Committee on Water  
 Canadian Committee on Climatic Fluctuations and Man

- V.A. Glooschenko**  
 Peat Environmental Committee  
 Editorial Board, "Geoscience Canada"  
 DOE Coal Group  
 National Wetlands Working Group  
 Canadian Committee on Ecological Land Classification  
 Society of Wetland Scientists — President 1983/84

- D.R.S. Lean**  
 Standard Methods Advisory Group

- S. Painter**  
 Aquatic Plant Harvesting Guidelines Committee  
 Aquatic Plant Management Society, local chapter's committee

- O. Nriagu**  
 Canadian National Committee for SCOPE  
 SCOPE Scientific Committee on Metal Cycles

International Committee for Symposia on Environmental Biogeochemistry

Editorial Board, "Chemical Geology"

Editorial Board, "Tellus"

Associate Editor, "Science of the Total Environment"

Editor, "Advances in Environmental Science and Technology"

Editorial Board, "Reclamation and Revegetation Research"

NRC Associate Committee on Scientific Criteria for Environmental Quality, Subcommittee on Heavy Metals

## PUBLICATIONS

*Barica, J.* 1982. Lake Erie Oxygen Depletion Controversy. *J. Great Lakes Res.* 8: 719-722.

*Barica, J., J. Gibson and W. Howard* 1983. Feasibility of Snow Clearing to Improve Dissolved Oxygen Conditions. *J. Fish. Aquat. Sci.* 40: 1526-1531.

*Barica, J.* 1983. Climate and Water Quality. *UN-WCP Newsletter* 4: 7.

*Barica, J.* 1984. Empirical Models for Prediction of Algal Blooms and Collapses, Winter Oxygen Depletion and Freeze-Out Effect in Lakes: Summary and Verification. *Verh. Internat. Verein. Limnol.* (In press).

*Bourbonniere, R.A.* and I.P. Martini 1982. The Origin of Hydrocarbons, their Geochemistry, Maturation and Migration. Proceedings of the 21st Annual Ontario Petroleum Institute Conference, 13, 23 pp.

*Bourbonniere, R.A.* and P.A. Meyers 1982. Characterization of Sedimentary Humic Matter by Alkaline Hydrolysis. *Organic Geochemistry*, 5(3).

*Brownlee, B.G.* and *T.P. Murphy* 1983. Nitrogen Fixation and Phosphorus Turnover in a Hypertrophic Prairie Lake. *Can. J. Fish. Aquat. Sci.*, 40: 1853-1860.

*Burnison, B.K.* 1983. "Colloidal" Phosphorus Errors in Gel Chromatography. *Can. J. Fish. Aquat. Sci.*, 40: 1614-1621.

*Burnison, B.K.* and *G.G. Leppard* 1983. Isolation of Colloidal Fibrils from Lake Water by Physical Separation Techniques. *Can. J. Fish. Aquat. Sci.*, 40: 373-381.

*Burnison, B.K.* and *G.G. Leppard* 1984. Ethanol Fractionation of Lacustrine Colloidal Fibrils. *Can. J. Fish. Aquat. Sci.* (In press).

Carey, J.H., M.E. Fox, *B.G. Brownlee*, J.L. Metcalfe, P.D. Mason and W.H. Yerex 1983. The Fate and Effects of Contaminants in Canagagique Creek 1. Stream Ecology and Identification of Major Contaminants. *Inland Waters Directorate Scientific Series No.* 135.

*Charlton, M.N.* and S.S. Rao 1983. Oxygen Depletion in Central and Eastern Lake Erie: Relationship with Bacteria, Chlorophyll, POC, and Morphometry. *J. Great Lakes Res.*, 9(1): 3-8.

*Charlton, M.N.* 1983. Downflux of Sediment, Organic Matter, and Phosphorus in the Niagara River area of Lake Ontario. *J. Great Lakes Res.*, 9(2): 201-211.

Cuhel, R., P. Ortner, and *D.R.S. Lean* 1984. Night Protein Synthesis by Algae. *Limnol. Oceanogr.* (In press).

*Delorme, L.D.* 1982. Lake Erie Oxygen: The Prehistoric Record. *Canadian Journal of Fisheries and Aquatic Sciences*, 39(7): 1021-1029.

*Delorme, L.D., S.R. Esterby* and H. Duthie 1983. Prehistoric Trends in pH for Kejimikujik Lake, Nova Scotia. *Internat. Revue Gesam. Hydrobiologie*, 68 (In press).

*Delorme, L.D.* and S.C. Zoltai 1984. Distribution of an Arctic Ostracod Fauna in Space and Time. *Quaternary Research* (In press).

El-Shaarawi, A.H. and *L.D. Delorme* 1982. The Change-Point Problem for a Sequence of Binomial Random Variables. IN: A.H. El-Shaarawi and S.R. Esterby (ed.) *Time Series Methods in Hydrosociences*, Elsevier Scientific Publications Co., Amsterdam, p. 68-75.

El-Shaarawi, A.H. and *S.R. Esterby* 1982. Inference about the Point of Change in a Regression Model with a Stationary Error Process. IN: A.H. El-Shaarawi and S.R. Esterby (ed.) *Time Series Methods in Hydrosociences*, Elsevier Scientific Publications Co., Amsterdam, p. 55-67.

El-Shaarawi, A.H. and *S.R. Esterby* and K. Kuntz 1983. A Statistical Evaluation of Trends in the Water Quality of the Niagara River. *J. of Great Lakes Research*, 9(2): 234-240.



**Esterby, S.R.** 1982. Fitting Probability Distributions to Bacteriological Data: Considerations for Regulations and Guidelines. *J. Fr. Hydrol.*, 13: 189-203.

**Esterby, S.R.** and **L.D. Delorme** 1983. Calibration in Paleoclimatology when the Response is Binary. Preprint, Statistical Climatology, Lisbon, September.

**Glooschenko, W.A.** 1983. Salt Marsh Vegetation of the Ontario Coast of Hudson and James Bay. Part 1. Transect Description. NWRI Report 83-23, 55 pp.

**Glooschenko, W.A.** and **A. DeBenedetti** 1983. Atmospheric Deposition of Iron from Mining Activities in Northern Ontario. *Sci. Total Environ.*, 29 (In press).

**Glooschenko, W.A.** and **N. Arafat** 1983. Sphagnum Moss as an Indicator of Airborne Deposition of Metals in the Rouyn-Noranda Area, Quebec. *Le Naturaliste Canadien*, 2(2).

**Glooschenko, W.A.** and **I.P. Martini** 1983. Vegetation Ecology of River-Influenced Coastal Marshes of the Southwestern End of James Bay, Ontario. *Can. J. Botany* (In press).

**Glooschenko, W.A.** and **I.P. Martini** 1983. Wetlands of the Ottawa Pisk at River Mouth, James Bay, Ontario, Canada. *Wetlands*, 3 (In press).

**Lean, D.R.S.** 1984. Metabolic Indicators for Phosphorus Limitation. *Verh. Internat. Verein. Limnol.* (In press).

**Lean, D.R.S., A.P. Abbott, M.N. Charlton,** and **S.S. Rao** 1983. Seasonal Phosphate Demand for Lake Erie Plankton. *J. Great Lakes Res.*, 9: 83-91.

**Leppard, G.G.** 1983. Editor: Trace Element Speciation in Surface Waters and its Ecological Implications. Plenum Publ. Corp., New York. 320 pp.

**Leppard, G.G.** 1984. What is in Your Water? NATO Sci. Publ. Newsletter (In press).

**Lewis, D.H., I. Wile** and **D.S. Painter** 1983. Evaluation of Terratrack and Aquascreen for Control of Aquatic Macrophytes. *J. Aquat. Plant. Manage.*, 21: 103-104.

**Manning, P.G., K.R. Lum** and **T. Birchall** 1983. Forms of Iron, Phosphorus and Trace-metal Ions in a Layered Sediment Core from Lake Ontario. *Can. Mineral.*, 21: 121-128.

**Mathias, J.A.** and **J. Barica** 1984. A Hypothesis to Explain Early Spring Mortality of Stocked Trout by Gas Supersaturation. *Can. J. Fish Aquat. Sci.* (In press).

**McQueen, D.J., S.S. Rao** and **D.R.S. Lean** 1984. Influence of Hypolimnetic Aeration on Bacteria Abundance. *Hydrobiologia* (In press).

**McQueen, D.J.** and **D.R.S. Lean** 1984. Hypolimnetic Aeration and Dissolved Gas Concentration: Enclosure Experiments. *Water Research* (In press).

**McQueen, D.J.** and **D.R.S. Lean** 1984. Aeration of Anoxic Hypolimnetic Water-Effects on Nitrogen and Phosphorus Concentrations. *Verh. Internat. Verein. Limnol.* (In press).

**Murphy, T.P., K.J. Hall** and **I. Yesaki** 1983. Biogenic Regulation of Iron Availability in a Eutrophic Hardwater Lake. *Sci. Tot. Envir.*, 28: 37-50.

**Nriagu, J.O.** 1983. Rapid Decomposition of Fish Bones in Lake Erie Sediments. *Hydrobiologia*, 106: 217-222.

**Nriagu, J.O.** 1983. Occupational Exposure to Lead in Ancient Times. *Sci. Tot. Envir.*, 31: 105-116.

**Nriagu, J.O.** and **H.K.T. Wong** 1983. Selenium Pollution of Lakes near the Smelters at Sudbury, Ontario. *Nature*, 301: 55-57.

**Nriagu, J.O.** 1983. Arsenic Enrichment in Lakes near the Smelters at Sudbury, Ontario. *Geochim. Cosmochim. Acta*, 47: 1523-1526.

**Nriagu, J.O.** and **R.D. Coker** 1983. Sulfur in Sediments Chronicles Past Change in Lake Acidification. *Nature*, 303: 692-694.

**Nriagu, J.O.** and **Y.K. Soon** 1983. Arylsulfatase Activity in Polluted Lake Sediments. *Environ. Pollut.* (In press).

**Nriagu, J.O.** 1983. Saturnine Gout Among Roman Aristocrats. *New Engl. J. Med.* 308: 660-663.

**Nriagu, J.O., H.K.T. Wong** and **W.J. Snodgrass** 1983. Historical Records of Metal Pollution in Sediments of Toronto and Hamilton Harbours. *J. Great Lakes Res.*, 9: 365-373.

**Oliver, B.G.** and **M.N. Charlton** 1983. Chlorinated Organic Contaminants on Settling Particulates in the Niagara River Vicinity of Lake Ontario. *Environmental Science and Technology* (In press).

**Pick, F.R.** and **D.R.S. Lean** 1984. Diurnal Movements of a Colonial Chrysophyte. *J. Phycol.* (In press).

**Pick, F.R.** and **D.R.S. Lean** 1984. Nutrient Status of Metalimnetic Phytoplankton Peaks. *Limnol. Oceanogr.* (In press).

**Rao, S.S., D. Paolini** and **G.G. Leppard** 1984. Effects of Low-pH Stress on the Morphology and Activity of Bacteria from Lakes Receiving Acid Precipitation. *Hydrobiologia* (In press).

**Rosa, F., J.O. Nriagu, H.K.T. Wong** and **N.M. Burns** 1983. Particulate Flux at the Bottom of Lake Ontario. *Chemosphere*, 12: 1345-1354.

**Rossmann, R., K.A. Johansen** and **R.A. Bourbonniere** 1982. Geochemistry of Lake Ontario Sediments. Unpublished report to Great Lakes Environmental Research Laboratory (NOAA).

**Wong, H.K.T., J.O. Nriagu** and **R.D. Coker** 1984. Atmospheric Input of Heavy Metals Chronicled in Lake Sediments of Algonquin Provincial Park. *Chemical Geology* (In press).

## AQUATIC PHYSICS AND SYSTEMS DIVISION

The Aquatic Physics and Systems Division of NWRI conducts a program of research incorporating balances of experimental measurements, and numerical theoretical analysis. The emphasis in this work is on understanding physical processes such as circulation, mixing, and diffusion, and their interrelationship with dissolved and suspended materials. In support of these and other research programs the Division maintains archives of environmental data and provides computer programming assistance. These responsibilities are shared among four sections: (i) Physical Limnology, (ii) Environmental Simulation, (iii) Environmental Optics, and (iv) Data Management.

### PHYSICAL LIMNOLOGY SECTION

The goals of the Physical Limnology program are to describe and to quantify physical processes in lakes. Of particular interest are processes such as mean transport and turbulent diffusion that affect water quality. These goals are approached through a combination of field observations, data analysis and interpretation, and theoretical or modelling studies.

**Lake Erie Studies.** Analysis of data collected in Lake Erie in 1979 and 1980 has continued. A numerical simulation of vertical transfers of heat and momentum using a turbulent energy budget approach (Dynamic Reservoir Simulation Model) and undertaken by J.C. Paterson (visiting scientist) and G.N. Ivey (PDF), has confirmed earlier analysis by Ivey and Boyce (1982) of episodes of entrainment into a turbulent hypolimnion. This study shows that downward entrainment characterized by simultaneous thickening and warming of the hypolimnion takes place only when the thermocline or metalimnion is sufficiently thick. When the thermocline is thin, the epilimnion and the hypolimnion are coupled directly and the more energetically mixed layer grows at the expense of the other. Further research is needed to determine the rules governing this process. Under contract to NWRI, J.C. Paterson and his associates coupled the DYRESM model with a dissolved oxygen model and obtained encouragingly realistic results. A. Zahawhary, Ph.D. candidate at McMaster University, is analysing temperature and current data taken near Cleveland, Ohio as partial fulfillment of his degree requirements. He has compiled a data report on this information and has recently completed an analysis of the mixing characteristics of the nearshore flow. The 1979, 1980 Lake Erie data is being used to test improved methods of storm-surge forecasting now under development. Louise Royer (NSERC post-doctoral fellow) is presently working on a description of water movements in mid-Central Basin. A final synthesis report of the Lake Erie experiments is being assembled jointly by NWRI, the Centre for Lake Erie Area Research (Ohio State University), and the Great Lakes Environmental Research Laboratory (NOAA, Ann Arbor, Michigan). The report will be published as a special issue of the Journal of Great Lakes Research in 1984. (Boyce)

**Lake Ontario Studies.** Extensive fieldwork was carried out in Lake Ontario in 1982. An array of current meters and thermistor chains was installed on the north shore of the lake between Ogden Point and Bowmanville, with transects running from Port Hope, Ontario to Point Breeze, New York, and from Toronto, Ontario, to the Niagara River

- w Motion package
- ▲ Meteorological station
- Tide gauge
- \* Fixed temperature profiler
- x Current meter — PL10m, GEO 1m off bottom
- Current meter — GEO at 30 and 50 m.
- + Wave rider

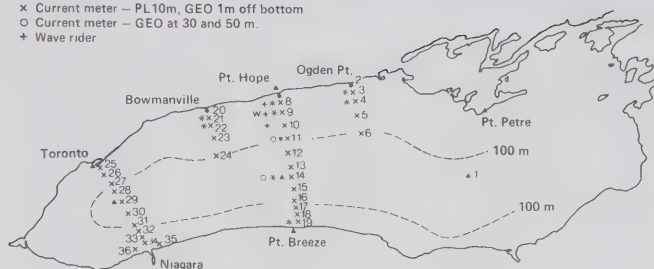


Figure 1 Lake Ontario — 1982 Mooring Locations

mouth (Fig. 1). This experiment was designed to test theoretical explanations of the current reversals observed to take place following episodes of strong winds. The northshore experiments ran through the summer and fall of 1982, while the transects remained in place through the winter (4 November, 1982 to 23 March, 1983). The winter observations show an intensification of eastward current near the south shore of the lake in contrast to the theoretical distribution which would call for a more equal distribution of eastward flow on both the north and south shores of the lake. This is a significant observation and an explanation is being sought.

The results of the Lake Ontario North Shore Study are valuable in the interpretation of the Lake Ontario Nutrient Assessment Surveys simultaneously conducted by the Aquatic Ecology Division.

In support of biochemical surveys conducted at the mouth of the Niagara River to determine the fate of potentially toxic chemicals entering the lake from the river, a series of seven, five day physical experiments was conducted in the area of the river mouth, from April to November, 1982. Three similar experiments were conducted in the summer of 1983. The purpose of these experiments, which included detailed EBT surveys and the tracking of clusters of drogues, was to delineate the horizontal distributions and flow characteristics of the plume of water emanating from the Niagara River. This information served to guide the biochemical sampling and as input to numerical simulations of the river-lake interaction. Experiments show that the plume is hydraulically controlled or jet-like within the first two or three km from the river mouth and beyond that, the plume is controlled by winds and ambient currents. A comprehensive report on the Niagara plume experiments will be published in 1984. (Murthy)

**Limnology of Yukon Lakes.** Responding to a need to assess the potential impact of hydroelectric power developments on watersheds in Northern British Columbia and the Yukon Territory, NWRI, Pacific and Yukon Branch, has undertaken a long-term study of selected lakes in that region.

NWRI Burlington, has contributed to that program. Under the leadership of P.F. Hamblin, a Neil Brown acoustic current meter was modified for use under an ice-



cover. A field experiment was carried out on Lake LaBerge in February, 1983 to determine the distribution of flow in a narrow, ice-covered lake. Modelling studies of ice-covered lakes have also been pursued in support of this program. P.F. Hamblin and G.N. Ivey conducted experiments in the Hydraulics Research Division cold room on vertical circulation and horizontal heat transfer in the vicinity of a thermal bar. (Hamblin)

**Other Activities.** A feasibility study was conducted during January and February 1983, in the canal connecting Hamilton Harbour with Lake Ontario, in order to find out whether water levels from each end of the canal could be transmitted by semi-rigid tubing to a sensitive differential pressure transducer, thus providing a direct measure of the mean sea-surface slope. Current meter observations were made in support of the slope measurements. Analysis has shown that the current observations are consistent with the water level observations (Simons, Schertzer, 1983). The concept will be further tested in the more demanding lake environment in the autumn of 1984. If successful, the technique could prove to be a valuable adjunct of more conventional measurements. (Boyce)

The Section continues to provide data processing services (subject to available resources) to outside agencies, such as Ontario Ministry of the Environment. Information and analyses have been provided to Ontario Ministry of Natural Resources (fish kill problem) (Boyce, Roach, 1983), Public Works Canada (nearshore circulation in Lake Erie), Ontario Hydro and Ontario Ministry of the Environment (Niagara River, Humber River, and 1983 Beach Closures, etc.).

## ENVIRONMENTAL SIMULATION SECTION

The main objective of the Environmental Simulation Section is to develop and maintain a modelling capability for the integration of research results and data from the various disciplines of water sciences. This is achieved by developing a general modelling framework which can be readily adapted to address a wide range of environmental problems such as lake eutrophication, toxic contamination and watershed acidification. The purpose of the models is threefold: to make predictions and provide guidelines and trend analysis for environmental management problems; to provide feedback to the ongoing research and monitoring programs on the gaps of knowledge; and to maintain a strong focus of systems modelling expertise in APSD and consolidate modelling efforts by close collaboration with other divisions.

**Niagara River Plume Model.** The modelling study on the Niagara River plume forms part of the research teamwork shared by physical limnologists, chemists and ecologists. Its main thrust has been on the simulation of the complex transport and dispersion processes in the plume, as the major environmental concern is on the fate and pathways of the toxic substances found in the river. From past efforts, a hierarchy of hydrodynamic and transport models has been already implemented operationally. The application of these existing models to the case of the Niagara River was quite straightforward and involved the use of nested grid techniques. First, a lakewide hydrodynamic model with a coarse (5 km x 5 km) grid was applied to the entire lake; then, an intermediate size (1 km x 1 km) grid was used for the coastal zone (Fig. 2) near the river with the boundary conditions defined by the coarse grid results; finally, a fine (0.2 km x 0.2 km) grid was imposed on the river itself using solutions with the intermediate size

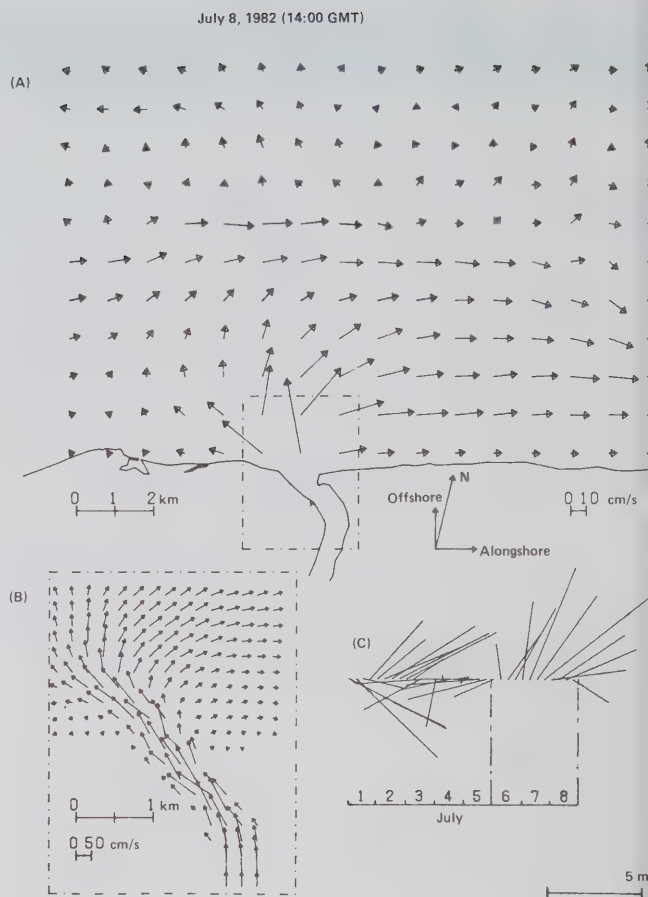


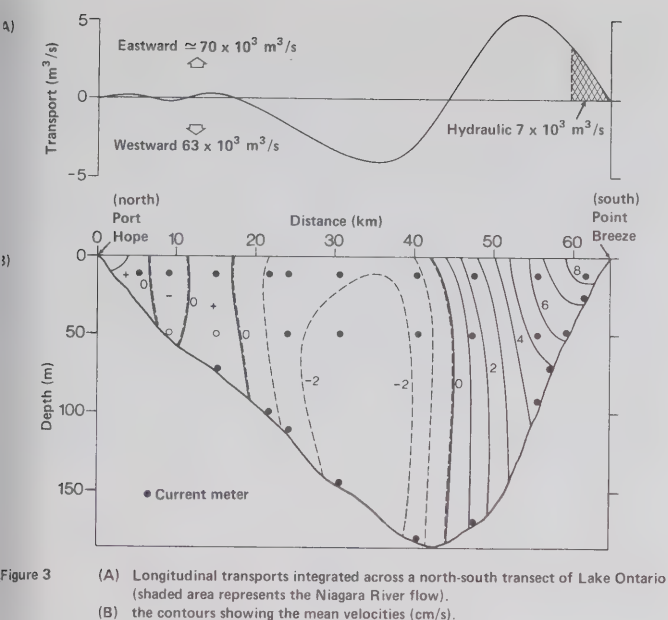
Figure 2 (A) Computed currents with 1 km x 1 km grid; (B) computed currents with 0.2 km x 0.2 km grid; (C) observed winds.

grid as boundary conditions. This telescoping technique has the advantage of not having to use the fine grid over the entire lake and still achieving reasonable accuracy near the river.

The computed hydrodynamic currents were found to be capable of simulating the observed drogue movements satisfactorily, showing the distinctive effects of the near river flow; the ambient currents; and the environmental turbulent diffusion. These plume characteristics have been used by the chemists for a better grid resolution in the sampling strategy. (Simons, Lam)

An ecological model incorporating the toxic substance processes has also been developed, following the food chain of benthic organisms, plankton, and fish for the Niagara River area. This model is based upon the average transports obtained by the above hydrodynamic model. Verification of this model awaits availability of biological and chemical data. (Halfon)

**Circulation in a North-South Transect of Lake Ontario** Whereas the hydraulic flow of the Niagara River exerts considerable influence over the transport and dispersion of pollutants in its immediate vicinity, the offshore circulation is affected mainly by wind forcing, earth's rotation and other geophysical factors. A good example is shown in Figure 3(a) in which the interpolated total longitudinal transport (+ denotes eastward flow; — denotes westward flow) is depicted for a transect across Lake Ontario from Port Hope, Ontario to Point Breeze, N.Y. Here, the hydraulic flow represents only about 10% of the total



eastward transport. The circulation is dominated by a strong eastward flow along the south shore and a return flow in the middle part of the lake. Similar but smaller circulation gyres can be found near the north shore.

The implication of these gyre formations is that contaminants originating along the south shore will be transported by the strong alongshore eastward current (Fig. 3(b)) and some of them will be returned westward when they reach the middle portion of the lake because of lateral dispersion. A more detailed analysis of the data is being carried out as to the frequency of occurrences of such episodes. A hydrodynamic model for the transect has been developed to study the downwelling and upwelling events thought to be crucial for the nutrient regeneration cycle in this region of the lake. (Simons)

**Port Granby Radionuclide Transport Model.** Port Granby radioactive waste disposal site is a 10 hectare area located on a bluff 25 m above lake level, on the north shore of Lake Ontario, approximately 15 km west of Port Hope, Ontario. Hydrogeologically, the strata in descending order are: (i) a moderately permeable unit of upper sandy clay silt; (ii) a unit of glacial till of low permeability; (iii) a moderately permeable unit of lower sands and silts; (iv) a unit of glacial till of low permeability; and (v) a moderately permeable unit of fractured bed rock aquifer. The site is bounded on three sides by groundwater drains: East Creek, West Creek and Lake Ontario. A two-dimensional finite element method was used to simulate groundwater flow patterns along several north-south geological cross sections through the site. The calibrated model simulates the water table, including the location of a groundwater divide, the hydraulic head distribution and the velocity flow field. The groundwater divide indicates that all of the recharging water is flowing to the deeper formations and discharging to Lake Ontario. Springs were also observed along the contact between the glacial till unit and upper sandy clay silt strata. Contaminant plumes of radium-226, uranium and nitrate have been computed by a two-dimensional finite element model and the results (Fig. 4) were found to compare satisfactorily with the data collected by the Radionuclides Section of ECD. Current efforts are being devoted to the interfacing of the groundwater transport model with the previously developed coastal zone effluent transport

model to determine the pathways of the radionuclides. (Bobba)

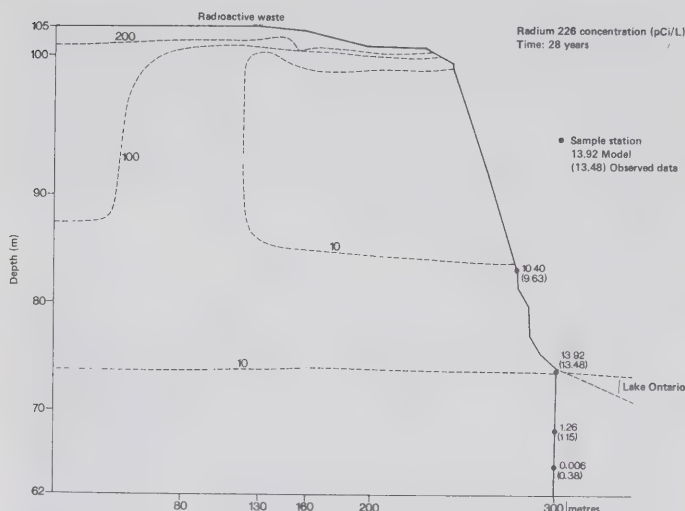


Figure 4 Simulated dilution contours of contaminant concentration at the Port Granby site.

**Turkey Lakes Watershed Acidification Model.** The Turkey Lakes Watershed is a completely forested, headwater drainage basin located 50 km north of Sault Ste. Marie, Ontario. An integrated observational study, co-ordinated by the Acid Deposition Section of ECD has been conducted since 1979 on the biological, chemical, hydrological, geological and meteorological aspects of the basin. The 10.5 km<sup>2</sup> watershed contains five interconnected lake sub-basins and numerous small streams. The headwater lake (Batchawana Lake) at 497 m above mean sea level, has the lowest pH, Ca<sup>++</sup>, alkalinity and carbon uptake rate. There is a general spatial gradient of these parameters across the watershed with the lower portions being the less acidic and more productive.

While the atmospheric deposit of acids is moderate (rain pH = 4.5) and uniform over the whole basin, and so is the availability of nutrients, these differences in both the acidity and the primary production among the lakes over such a small area stand out prominently in the data.

In order to explain this phenomenon, a watershed acidification model has been developed and modularized to take into account the snowmelt, surface runoff, stream flows, lake stratification, soil layer chemistry, canopy effects, unsaturated zones and groundwater flows. The model shows that at the headwater basin, the buffering capacity has been depleted substantially and the pH could drop to below 5, particularly after snowmelt events. The carbon uptake rates due to primary production are affected adversely by the low alkalinity, although there are nutrients available.

By contrast, at the lower portions of the watershed, cation exchange occurs more freely and groundwater flows appear to enhance primary production. An interesting example is the Little Turkey Lake (the fourth in the series) where a major influx of Ca<sup>++</sup> and Mg<sup>++</sup> from the groundwater appears to occur at the lake bottom almost all year around. In the summer period, this lake is thermally stratified but the favourable alkalinity and nutrient conditions in the epilimnion still sustain relatively higher



primary production than Batchawana Lake.

The complexity of the model development has necessitated the collaboration of the other Divisions at NWRI and several government agencies. (Lam)

**Long Range Transport of Airborne Pollutants: Empirical Modelling and Analysis.** A multivariate factor analysis which discriminates major influences on the chemistry of natural waters was undertaken, examining regions in Newfoundland, Nova Scotia, Quebec and Ontario (Thompson). By use of this procedure, five major factors have been identified: (1) seasalt from marine sources; (2) chemical weathering; (3) long range transport; (4) terrestrial dust; and (5) industrial emissions.

Factor analysis for 15 variables on precipitation chemistry data for Sept-Iles, Quebec clearly showed long range transport effects as factor 1, with pH loaded in opposition to sulphate accounting for 40% of the total variance. Clustering of chloride, sodium, and magnesium on factor 2 (21% of variance) identified the marine effect, and illustrated the need for adjustments in the data where long range transport or terrestrial effects are to be determined accurately. Effects of local industry and development were indicated by clustering of iron, lead, and zinc on factor 3 (10% of variance). Terrestrial dust of agricultural origin was indicated by clustering of total phosphorus, potassium, calcium, and nitrate on factor 4 (9% of variance).

An examination of sulphur yields of Quebec rivers was undertaken to determine the retention of depositional sulphate within watersheds in regions of Quebec, lying within the continental deposition plume (Thompson). As an example, Figure 5 shows the sulphur yields for the major rivers located in the Eastern Townships of Quebec. The resultant yields of sulphur generally follow the known pattern of atmospheric wet deposition. High sulphur yields which exceed the expected levels, are associated with highly populated and industrialized areas and include municipal, terrestrial and dry depositional sources. (Thompson)



Figure 5 Sulphur yields of rivers in the Eastern Townships of the Province of Quebec (g.m<sup>-2</sup> yr<sup>-1</sup>)

**Eutrophication Modelling.** The eutrophication process in lake waters is a complex phenomenon which depends upon the hydrodynamic, chemical, physical, biological and geological characteristics of the water body of interest. To take into account all these phenomena in a mathematical model is very difficult. Thus Ecological Modellers usually analyze only a few factors at a time.

Phosphorus is a nutrient which is often a limiting factor in the eutrophication of a lake, thus knowledge of the rates and pathways of phosphorus cycling in a water body is very important to determine the trophic state of a lake. Mathematical models can be used to quantify the cycling rates through the various components of the ecosystem e.g. phytoplankton, zooplankton, colloidal matter, water. A large scale mathematical model may require too much information from field experiments to quantify all parameter values. When information is incomplete, a smaller mathematical model is preferred. System identification techniques can be used to determine the minimum number of components required to model the phosphorus dynamical behaviour, and assist planning field programs to collect optimum number and types of samples.

A four compartment model proposed by D. Lean (1973) accounting for only soluble phosphorus, colloidal phosphorus, organic phosphorus compounds and particulate phosphorus was applied to data from Kootenay Lake, B.C. Results indicate that the model is adequate to describe the fresh water phosphorus cycle. (Halfon)

## ENVIRONMENTAL OPTICS SECTION

The Environmental Optics Section of APSD carries out both experimental and theoretical research concerned with the optical properties of the aquatic environment. The techniques of spectro-optical physics and radiative transfer theory are utilized, in conjunction with multi-spectral data acquired by *in situ* and remote (airborne and satellite) optical sensors, to develop interpretive and predictive optical models and methodology, and to apply these methodologies to water resource issues and concerns.

The optical physics activity comprises a basic long-term research program upon which are superimposed short-term studies as the opportunity arises. During the past year, the Section's effort was concentrated on the Great Lakes. Some of the pertinent studies included:

- The application of a Ship-borne Radiometer Reflectance System (SRRS) to the remote determination of water quality (in terms of suspended mineral, suspended chlorophyll *a*, and dissolved organic carbon concentrations). Data collected over Lakes Superior and Ontario are currently being analyzed. (Jerome)
- Completion of a report dealing with the application of *in situ* irradiance reflectance measurements to water quality indicators stressing the importance of the specific absorption and specific scattering properties of lake waters; and describing, in both mathematical and non-mathematical terms, the conditions under which realistic descriptions of lake water quality may be obtained from direct measurements of optical parameters. (Bukata)
- Completion of a comprehensive evaluation of the use of chromaticity (a tri-color separation of the natural irradiation incident upon a water body) in the remote measurements of water quality. Standard CIE chromaticity analyses were applied to upwelling irradiance spectra at the air/water interface. Results illustrate dramatically, the conditions under which such chromaticity techniques may

be applied with reasonable confidence; and those conditions within the aquatic environment which present severe restrictions to the application of chemotacticity to water quality measurement. (Bukata)

(d) Work was completed and published concerning the pitfalls associated with attempts to infer acid stress in lakes (pH does not, of its own, induce a color change in water) from passive satellite spectral data (which measure water color). This is an area which, perhaps largely due to an understandable zeal to apply the large wealth of acquired satellite data to acid lake concerns, is resulting in both misunderstanding and controversy, and should be carefully approached by both the generators and users of such remote sensing methodologies. (Bukata)

(e) The Section's final effort in subsurface contaminant transport (prior to the transfer of this effort to the newly formed Environmental Simulation Section) was the determination of diffusion coefficients (molecular and bioturbation) associated with the transport of  $^{210}\text{Pb}$  radionuclides in lake bed sediments. This work emphasizes the significance of bioturbation effects (assumed a direct consequence of the burrowing activity of benthic organisms) in the description of contaminant transport through the sediment of the Laurentian Great Lakes. (Bukata)

(f) Work is nearing completion on the generation of an "optical atlas" describing the Great Lakes in terms of optical data collected during the past CCIW programs. (Jerome)

## DATA MANAGEMENT SECTION

The Data Management Section of APSD, NWRI provides all components at the Canada Centre for Inland Waters with operational data management and EDP software development services. The corporate data archives of NWRI are maintained and managed for support of the NWRI research and IWD-OR operational programs. The Global Environmental Data Base for Water Quality is also maintained.

**Major Activities.** Software system design and development support were provided for 62 different studies within 15 organizational components at CCIW.

The major Acid Rain data base system and analysis facilities were expanded to meet added study requirements for the LRTAP program.

The major automated laboratory data acquisition systems were moved to a VAX 11/750, and training was provided for Water Quality Branch technicians.

The UNEP/UNESCO Global Environmental Monitoring System for water (GEMS/WATER) was enhanced and operated. A directory of stations, labs and personnel involved in the project was produced, along with a data summary for 1979-1981.

Interactive graphics facilities in support of research were developed including implementation of new digitization hardware and software. Interactive time-series data editing using color graphics was implemented (Fig. 6).

A Centrewide review and long-term projection of program-related computing requirements was completed. Conversion requirements were documented, benchmark programs selected, and alternatives were further evaluated.

A number of administrative data bases were implemented on the Cyber computer.

The Management Information System to support program planning was implemented on behalf of NWRI management.

**Technology Implementation.** System 2000 data base management now includes all corporate data bases, providing vastly improved access to data.

Major operational data bases such as Great Lakes surveillance and global (GEMS/WATER) data have been micrographically reproduced and distributed to government and university libraries. The GEMS microfiche were distributed to WHO headquarters, Geneva, and to six global regions.

Introductory and advanced computer courses presented by DMS drew total attendance in excess of 200 during the past year.

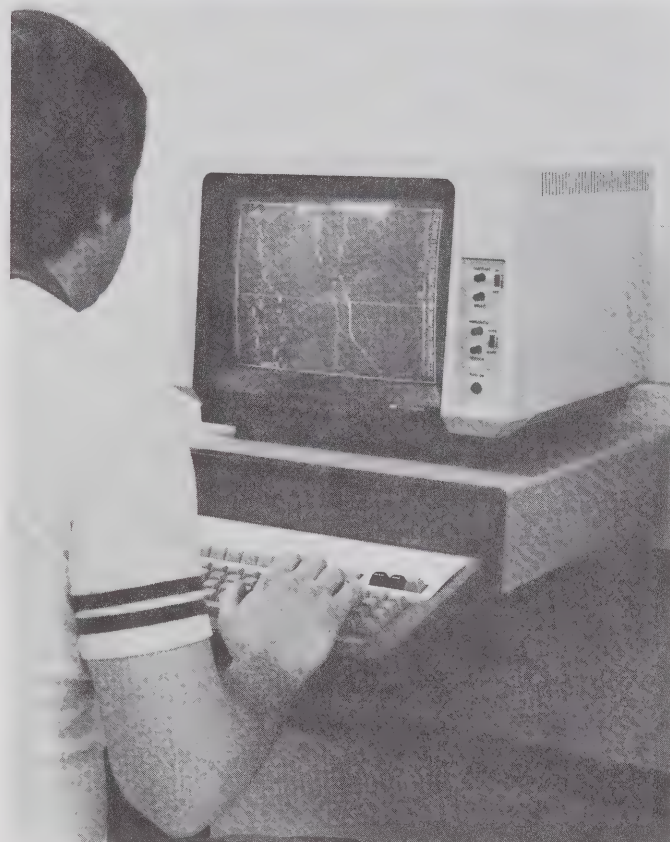


Figure 6 Interactive graphics being used for editing of time-series data.



## STAFF LIST

**Chief — Mr. Floyd C. Elder**  
**Secretary — Mrs. Sandy Tapping**  
**Administrative Officer — Mr. S.C. Smith**

### Physical Limnology

Head, Mr. F.M. Boyce      physical limnology

### Researchers

Mr. J. Bull      physical limnology  
 Mr. K. Miners      coastal zone research  
 Mr. F. Chiocchio      physical limnology  
 Mr. D. Robertson      physical limnology  
 Mr. M. Kerman      physical limnology  
 Dr. C.R. Murthy      physical limnology  
 Dr. P. Hamblin      physical limnology

### Environmental Optics

Head, Dr. R.P. Bukata      lake optics and satellite studies

### Researchers

Mr. J.E. Bruton      lake optics remote sensing  
 Mr. J. Jerome      lake optics remote sensing

### Environmental Simulation

Head, Dr. D. Lam      water quality monitoring

### Researchers

Mr. G. Bobba      hydrogeology and remote sensing  
 Mr. A. Fraser      water quality monitoring  
 Dr. T. Simons      hydrodynamic modelling  
 Mr. W. Schertzer      water quality modelling  
 Dr. M.E. Thompson      aquatic effects of LRTAP  
 Dr. E. Halfon      toxic substance modelling  
 Dr. A. El-Shaarawi      statistical modelling

### Data Management Section

Head, Mr. J. Rogalsky      data management services  
 (retired 1 January 1984)  
 Mr. R. Duffield (A/Head)      data base administration

### Computer Programmers

Mr. A. Zingaro      software development  
 Mr. S. Beal      microcomputer applications  
 Mr. W. Nagel      data archiving  
 Mr. J. Byron      data archiving  
 Mrs. J. McAvella      data archiving  
 Mrs. H. Comba      software development  
 Ms. C. Minnie      word processing  
 (resigned August 1983)  
 Mr. B. Hanson      software development  
 Ms. J. Dowell      software development  
 Mr. J. Hodson      software development  
 Mr. U. Ventresca      software development  
 Mrs. K. Miles      software development

## COMMITTEE MEMBERSHIP

### C.R. Murthy

DOE Working Group on Environmental Codes of Practice for Steam Electric Generating Stations

### D.C.L. Lam

Editorial Board, "International Journal of Advances in Water Resources"

IJC Great Lakes Modelling Task Force

Ph.D. Candidate Supervisory Committee, Department of Civil Engineering, McMaster University

Executive Council, Canadian Applied Mathematics Society — Vice-President

### P.F. Hamblin

Associate Editor, "Physical Limnology Journal of Great Lakes Research"

Ph.D. Candidate Supervisory Committee, Department of Civil Engineering, McMaster University

International Association for Great Lakes Research, Membership Committee

### A.H. El-Shaarawi

Biometrics Subcommittee — Vice Chairman

Head, Descriptive Mathematics Section, American Society for Testing of Material

### A.S. Fraser

IJC Working Group on Data Management and Interpretation

### F.M. Boyce

Associate Editor "Atmosphere Oceans" (Journal of Canadian Meteorological and Oceanographical Society)

Scientific Committee, CMOS 1983-1986

Board Member, IAGLR 1983-1986

Rapporteur, Oceanography, Canadian Geophysical Bulletin

### E. Halfon

Directors Board, International Society of Ecological Modelling, North American Chapter

Ph.D. Candidate Supervisory Committee, Department of Systems Science, State University of New York, Binghamton

### W.M. Schertzer

CCIW Physical Studies Seminar Series — Chairman

IWD Hydrologic Research Program Committee

Ontario Regional Climate Advisory Committee

### M.E. Thompson

Associate Editor, "Hydrological Sciences Journal"

Ph.D. Supervisory Committee for Moira Wadleigh

### F.C. Elder

Federal/Provincial LRTAP Research and Monitoring Coordinating Committee, Co-chairman of Aquatic Effects Subcommittee

Environmental Conservation Service, LRTAP Steering Committee, IWD Member

Program Committee Chairmn, International Symposium on Acid Precipitation

Canada-Ontario Agreement, Great Lakes Surveillance Committee

Canada-Ontario Agreement, Federal/Provincial  
Phosphorus Task Force

Great Lakes Water Quality Program, Strategic  
Planning Workgroup

Great Lakes Water Quality Program, Eutro-  
phication Issues Workgroup

B. Duffield

IWD Information Technology Committee

IWD Security Committee

R.P. Bukata

Limnology Working Group, Canadian Advisory  
Committee on Remote Sensing — Chairman

Representative, CCIW Remote Sensing Specialty  
Centre, Canadian Advisory Committee on  
Remote Sensing

J.E. Bruton

Limnology Working Group, CACRS — Secretary

Computer Compatible Tapes Usage Working  
Group, CACRS

Toronto Hydrology Working Group

## PUBLICATIONS

Begbeli, S., R. Guidazi, F. Terragni, and E. Halfon 1982. Identification of Phosphorus Dynamics in Kootenay Lake, Canada. *Ecological Modelling*, 17: 11-32.

Blumberg, A., R. Ferrara, W.G. Gray, D.C.L. Lam, D. Lynch and P. Sheng 1983. Physics Based Modelling of Lakes, Reservoirs and Impoundments. A.S.C.E. Monograph Series, 45 p. (In press).

Boyce, F.M. and W.M. Schertzer 1982. Summary of Lake Erie Workshop — IJC Offices, Windsor, Ontario, 29-30 November 1982. NWRI Unpublished Report, 26 p.

Boyce, F.M. and K. Roach 1983. Fish Mortality Along the North Shore of Lake Erie between Point Pelee and the Mouth of the Detroit River, November 6-7, 1982; Assessment of Physical Limnological Conditions. NWRI Unpublished Report, 12 p.

Boyce, F.M., D.G. Robertson and G.N. Ivey 1984. Summer Thermal Structure of Lake Ontario off Toronto: Cooling the Big City. *Atmosphere Ocean* (In press).

Bukata, R.P., J.E. Bruton and J.H. Jerome 1982. The Futility of Using Remotely-Determined Chlorophyll Concentrations to Infer Acid Stress in Lakes. *Can. J. Remote Sensing*, 8: 38-41.

Bukata, R.P., J.E. Bruton and J.H. Jerome 1983. On the Use of Chromaticity in the Remote Measurements of Water Quality. *Remote Sensing of Environment*, 13: 161-177.

Bukata, R.P., J.E. Bruton and J.H. Jerome 1983. Application of Direct Measurements of Optical Parameters to the Estimation of Lake Water Quality Indicators. NWRI Unpublished Report.

Bukata, R.P. and A.G. Bobba 1983. Determination of Diffusion Coefficients Associated with the Transport of  $^{210}\text{Pb}$  Radionuclides in Lake Bed Sediments. *Environ. Geol.* (In press).

El-Shaarawi, A.H. (1983). Goodness of Fit Statistics for the Generalized Power Series Distributions. *Bulletin of the International Statistical Institute*, 1: 191-194.

El-Shaarawi, A.H., S.R. Esterby and K.W. Kuntz (1983). A Statistical Evaluation of Trends in the Water Quality of the Niagara River. *J. Great Lakes Res.*, 9(2) 234-240.

Esterby, S.R. and A.H. El-Shaarawi. Coliform Concentration in Lake Erie — 1966 to 1970. *Hydrobiologia*, (In press).

Anderson, J.E., A.H. El-Shaarawi, S.R. Esterby and T.E. Unny (1984). Dissolved Oxygen Concentrations in Lake Erie (U.S.A./Canada): 1. Study of Spatial and Temporal Variability Using Cluster and Regression Analysis. *J. of Hydrology*, 72(3/4).

El-Shaarawi, A.H. (1984). Dissolved Oxygen Concentrations in Lake Erie (U.S.A./Canada): 2. A Statistical Model for Dissolved Oxygen in the Central Basin of Lake Erie. *J. of Hydrology*, 72(3/4).

A. Maul and A.H. El-Shaarawi (1984). Dénombrement et Mesures d'activité des bactéries. Chapitre 9. Bactériologie des Milieux Aquatiques: Aspects Ecologiques et Sanitaires, Metz (Coordinateur: G. Martin).

El-Shaarawi, A.H. and M.A. Neilson (1984). Changes in Nutrient Levels of Lake Water Stored at 4°C. *Canadian Journal of Fisheries and Aquatic Sciences*, (In press).

El-Shaarawi, A.H. and M.A. Neilson (1984). Should Nutrient Analysis of Water Samples be Performed on-board Ship? IWD Scientific Series, (In press).

Dutka, B.J., K. Walsh, A.H. El-Shaarawi and R.S. Tobin (1984). Environmental Distribution Patterns of *Legionella* in Central Canada and Longevity Studies. NWRI Unpublished Manuscript.

El-Shaarawi, A.H. (Ed.) (1984). Statistical Assessment of the Great Lakes Surveillance Program, Lake Erie. IWD Scientific Series 136, 347 p.

El-Shaarawi, A.H. and J. Whitney (1982). On Determining the Number of Samples Required to Estimate the Phosphorus Input Contributed by Niagara River to Lake Ontario. IN: O.D. Anderson (Ed.) *Time Series Analysis: Theory and Practice* 1. North Holland, p. 271-286.

Graham, E. and F.M. Boyce 1983. The Influence of Morphometry upon Thermal Stratification and the Depth of the Summer Thermocline. NWRI Unpublished Report, 47 p.

Halfon, E. 1982. Uncertainty in Modelling the Environmental Fate of Mirex in Lake Ontario. IN: L. Troncelle (ed.) *A General Survey of Systems Methodology*. Society for General Systems Research, 553-558.

Halfon, E. 1983. Uncertainty Analysis in Ecological Modelling. IN: *State of the Art in Ecological Modelling*. Elsevier, Amsterdam 655-662.

Halfon, E. 1983. Organic Contaminants Lake Model for the Prediction of Transient Water Quality in the Niagara River Plume, Lake Ontario. NWRI Unpublished Report, 82 p.

Halfon, E. 1983. Is There a Best Model Structure? I. Modelling the Fate of a Toxic Substance in a Lake. *Ecological Modelling*, 20: 135-152.

Halfon, E. 1983. Is There a Best Model Structure? II. Comparing the Model Structure of Different Fate Models. *Ecological Modelling*, 20: 153-163.

Hamblin, P.F. 1982. On the Free Surface Oscillations of Lake Ontario. *Limnol. Oceanogr.*, 27(6): 1039-1049.

Ivey, G.N. and F.M. Boyce 1982. Entrainment by Bottom Currents in Lake Erie. *Limnol. Oceanogr.*, 27(6): 1029-1038.

Jedrasik, J. and T.J. Simons 1983. Comparison of Different Procedures for the Simulation of Temperature Oscillations in Radunia Lake, Poland. *Limnol. Oceanogr.*, 28: 1014-1020.

Jerome, J.H., R.P. Bukata and J.E. Bruton 1983. Effect of Solar Zenith Angle Diurnal Variations on Estimation of Primary Production and Irradiation. NWRI Unpublished Report.

Jerome, J.H., R.P. Bukata and J.E. Bruton 1983. Spectral Attenuation and Irradiance in the Laurentian Great Lakes. *J. Great Lakes Res.*, 9: 60-68.

Jerome, J.H., R.P. Bukata and J.E. Bruton 1983. A Mathematical Procedure for Determining the Average Irradiance Attenuation Coefficient of Natural Waters. *Appl. Opt.*, 22: 515-517.

Lam, D.C.L., W.M. Schertzer and A.S. Fraser 1982. Mass Balance Models of Phosphorus in Sediments and Water. *Hydrobiologia*, 91: 217-225. W. Junk Publishers, The Hague, Netherlands.

Lam, D.C.L., C.R. Murthy and R.B. Simpson 1983. Effluent Transport and Diffusion Model for the Coastal Zone. *Lecture Notes Series on Coastal and Estuarine Studies*, 251 p. Springer-Verlag, N.Y., Publishers (In press).

Lam, D.C.L., W.M. Schertzer and A.S. Fraser 1983. Simulation of Lake Erie Water Quality Response to Loading and Weather Variations. IWD Scientific Series No. 134, 301 p.

Lam, D.C.L. and R.W. Durham 1983. Finite Element Analysis of a Radioactive Tritium Patch and a Waste Heat Plume Observed Near the Pickering Nuclear Power Generating Station, Lake Ontario. *J. Great Lakes Res.*, 9: 26 p.

Lam, D.C.L. and L. Somlyódy 1983. An Intercomparison Between the Lake Erie and Lake Balaton Water Quality Study. *Proc. IASA/MTA Workshop in Eutrophication of Shallow Lakes: Modelling, Monitoring and Management*. Veszprém, Hungary, August 1982, 18 p.

Lam, D.C.L., W.M. Schertzer and A.S. Fraser 1983. Modelling the Effects of Sediment Oxygen Demand on Lake Erie Water Quality Conditions Under the Influences of Pollution Control and Weather Variations. Submitted to *Sediment Oxygen Demand Workshop*, 56th Annual Conf., Water Pollution Control Federation, Atlanta, Georgia, 26 p.

Patterson, J.C., P.F. Hamblin and J. Imbarger 1984. Classification and Dynamic Simulation of the Vertical Density Structure of Lakes. *Limnol. and Oceanogr.* (In press).

Sanderson, B.G., A. Okubo, and C.R. Murthy 1983. Lagrangian Analysis of Lake Erie Drogue Data. NWRI Unpublished Report, 94 p.



**Schertzer, W.M.** 1982. How Great Lakes Water Moves. IN: Decisions for the Great Lakes. Great Lakes Tomorrow, Section 1, Chapter 3, p. 51-64.

**Schertzer, W.M.** 1982. Physical Limnology of the Great Lakes. NWRI Unpublished Report, 40 p.

**Simons, T.J.** 1983. Comments on the Effects of Bottom Friction on Continental Shelf Waves. J. Phys. Oceanography, 13: 147-148.

**Simons, T.J.** 1983. Resonant Topographic Response of Nearshore Currents to Wind Forcing. J. Phys. Oceanography, 13: 512-523.

**Simons, T.J.** and **W.M. Schertzer** 1983. Analysis of Simultaneous Current and Pressure Observations in the Burlington Ship Canal. NWRI Unpublished Report, 27 p.

**Simons, T.J.** and **W.M. Schertzer** 1983. Seasonal Temperature Variations in a North-South Cross-Section of Lake Ontario. NWRI Unpublished Report, 16 p.

**Thompson, M.E.** 1982. The Cation Denudation Rate as a Quantitative Index of

Sensitivity of Eastern Canadian Rivers to Acidic Atmospheric Precipitation. Water, Air and Soil Pollution, 18: 215-226.

**Thompson, M.E.** 1982. Exchange of Marine Sodium for Calcium During Chemical Weathering in the Isle aux Morts River Basin, Newfoundland. Geochim. Cosmoch. Acta, 46: 361-365.

**Thompson, M.E.** and **M.B. Hutton** 1982. Sulfate in Lakes of Eastern Canada: Calculated Atmospheric Loads Compared with Measured Wet Deposition. NWRI Unpublished Report, 18 p.

**Thompson, M.E.** and **M.B. Hutton** 1982. The Mersey River, Nova Scotia 1954/55 and 1971 — A Critical Evaluation of the Earlier Data. NWRI Unpublished Report, 23 p.

**Thompson, M.E.** 1983. Factor Analysis Applied to Water Chemistry Data: Its Usefulness and Limitations. NWRI Unpublished Report, 9 p.

**Thompson, M.E.** 1983. Sulfur Yields of Quebec Rivers. NWRI Unpublished Report, 8 p.

## ENVIRONMENTAL CONTAMINANTS DIVISION

The Environmental Contaminants Division investigates in the field and in the laboratory, the pathways, fate and effects of five groupings of contaminants: organic chemicals, toxic metals, organo-metallics, radionuclides, and ions associated with acid rain. Research information produced by the Division is valuable in substantiating recommendations for water management actions in polluted river basins. These actions may involve control of effluents, banning of chemicals, guidelines for consumption of biota or water, and many other procedures which can be implemented in Canada. Data may be valuable in negotiations on water quality matters, either interprovincially or internationally. Much of the published information is equally valuable as part of the total input required for toxic chemical assessments. Division activities are carried out in five sections as follows.

### ORGANICS PATHWAYS SECTION

The objective of this Section is to resolve the entry, fate, distribution, and transfer of organic contaminants in aquatic ecosystems. Research is conducted at specific polluted aquatic ecosystems, in experimental ponds, and in the laboratory. Intercompartmental transfer (water, suspended sediment, sediment, benthic fauna, and flora) and effects of organic contaminants are examined. Atmospheric input of organic contaminants to the aquatic environment is being studied.

**Pathways of Niagara River Contaminants in Lake Ontario.** A relationship was found to exist for some contaminants between concentrations on river suspended solids, Lake Ontario surficial sediments and amphipods. However, many of the Niagara River contaminants appeared to be in the "dissolved" form rather than associated with suspended solids. The initial movement of these compounds in Lake Ontario will be determined by the dynamics of the river plume. This study was therefore divided into two parts:

- a) A sediment, benthos, and fish survey designed to continue the investigation of bioaccumulation of two different classes of contaminants.
- b) A study of the transport of contaminants in the Niagara River plume.

Sediment, interface water, fish and benthos were collected from sites in Lake Ontario near the Niagara River and from reference sites to the east and west of the river mouth. Chlorobenzene levels were higher in amphipods than in oligochaetes while the reverse was true for chlorophenols. There appears to be poor correlation between sediment levels and benthos concentrations of these contaminants.

Chlorobenzenes were selected as a chemical marker of the Niagara plume because these compounds were easily detectable in river water but were generally absent from the surface waters of Lake Ontario. Concurrently the course of the plume was followed and plotted through the use of drogues. The chlorobenzenes were transported with the plume as it was influenced by weather conditions. Figure 1 shows the 1 m profiles of 1,2,3,4-tetrachlorobenzene under westerly and easterly wind conditions in May and October, 1982, respectively. Refinements to the sampling and analytical procedures in 1983 have permitted the examination of a wider variety of compounds. (Fox, Carey, Metcalfe, Coletta)

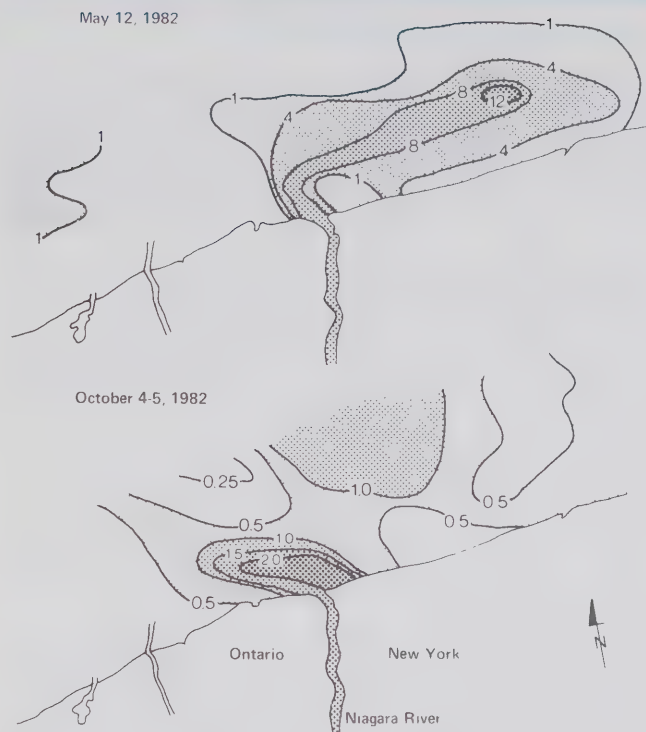


Figure 1 Tetrachlorobenzene in the Niagara River plume.

**Prediction of the Environmental Distribution of Toxic Chemicals.** The purpose of this project is to develop predictive systems to obtain good estimates of the distribution of organic chemicals in the environment. Three distribution models developed elsewhere are being translated to be run on micro-computers and are being compared for their sensitivity to small changes in input parameters.

Sorption on sediments is one of the major processes affecting the behaviour of chemicals in the aquatic environment. The process is characterized by a partition constant,  $K_d$ . A large sample of Lake Ontario sediment was fractionated using settling times to give coarse ( $\phi < 4$ ) and fine ( $\phi > 8$ ) fractions. These were freeze-dried to provide homogeneous and reproducible substrates. Samples of these fractions were suspended in water and equilibrated with hexachlorobenzene (HCB) and dichlorodiphenyl-dichloroethylene (DDE) at concentrations below their saturation levels.

Solubilities were also determined on a large number of replicates. The  $K_d$  values for HCB and for DDE, were in reasonable agreement with literature values. It appears that there is a negligible effect on  $K_d$  of the concentration of the suspended load. It also seems that there are no differences arising from the use of coarse or fine suspended sediments. (Strachan)

### Atmospheric Deposition of Persistent Organic Chemicals.

A major pathway for the entry of organic chemicals to the Great Lakes system and elsewhere is from the atmosphere. PCBs and DDT are substances which have been severely limited or banned from North American usage for more than ten years and yet they continue to appear in rainfall. An automated rain sampler was designed, built and evaluated as a collecting and concentrating device for per-



sistent organic chemicals in rain. Three samplers were installed on each of Isle Royale and Caribou Island in Lake Superior. Sample columns were collected from each sampler and analyzed for PCBs, toxaphene, and organochlorine pesticides. (Strachan)

**Pathways of Contaminants in Fluvial Systems.** Laboratory investigations are coupled with field work both at the Canagagigue Creek site (Elmira, Ontario) and at other locations across Canada. A survey of chlorophenol residues in the benthic community (Table 1) revealed that leeches have a high bioaccumulation potential for these compounds.

Table 1. Chlorophenol levels in biota and water from CN-3 in Canagagigue Creek.

Sample	Chlorophenol concentration (ppb)			
	2,4,6-TCP	2,4,5-TCP	2,3,4,6-TTCP	PCP
Leech ( <i>Dina dubia</i> )	2201	10 262	508	188
Leech ( <i>Glossiphonia complanata</i> )	639	1688	100	11
Leech ( <i>Helobdella stagnalis</i> )	371	2461	140	11
Snails ( <i>Physa</i> sp.)	25	27	7	11
Damselfly larvae ( <i>Zygoptera</i> sp.)	116	169	58	14
Cranefly larvae ( <i>Tipulidae</i> )	83	9	9	11
Water	0.065	0.083	0.007	11

Additional research goals were to define the bioconcentration curves for the various species of leeches, to identify the factors responsible for this high bioconcentration capacity and to evaluate the potential of leeches as biological indicators or "sentry" organisms. Only aquatic oligochaetes had comparable residues. In preliminary laboratory tests, specimens of the leech *Dina dubia* did not eliminate any of their body burden of chlorophenols within a two-week period in clean water. Leeches are ubiquitous and easy to sample. As they are not easily damaged during handling, they are ideal for laboratory up-take and depuration experiments. They are relatively sedentary and therefore representative of their immediate environment.

Four species of leeches in Canagagigue Creek were collected and analyzed for chlorophenol residues to compare the bioaccumulation potentials and to determine whether animal size is an important parameter in uptake. Results suggest that *Dina dubia* has the highest body burden of chlorophenols. As the life histories of Canadian leech species are very poorly known, a study on the age structure and food habits of three of our species was conducted. To expand the range of contaminants and leech species under investigation, studies of the Grand River watershed in Ontario and selected sites in New Brunswick were initiated.

A fish census of Canagagigue Creek revealed that most species avoided the highly contaminated areas, and that specimens of at least one species (rock bass) caught in these areas tended to be in poor condition. To provide good estimates of potential long-term hazards of chemicals, tests with sensitive early life stages of fish were carried out. Survival of the early life stages of the common shiner (*Notropis cornutus*) 1.7 km below the Elmira Water Pollution Control Plant (WPCP) was compared with survival at a clean site 2.3 km above the outfall. Survival to hatch was high at both sites. However survival to the critical swim-up stage was reduced from 69% upstream to 49% downstream. Rainbow trout fingerlings were reared for six weeks at the two sites described above. No differences in mortality or growth rates between sites were noted. The uptake rates of chlorophenols by trout will be described and levels of chlorophenols in trout and their

various organs will be compared with those of indigenous fish species.

Disappearance of chlorophenols from the stream showed weak seasonal fluctuation in rate, although levels vary occasionally by more than two orders of magnitude. Rate constants for this disappearance have been calculated and indicate that chlorophenols have a 6 to 10 hour half-life in the stream. This short half-life contrasts with a much longer time previously found in the Bay of Quinte, Ontario and indicates that the rate and pathways of degradation of contaminants is strongly dependent on the individual ecosystem. In Canagagigue Creek, the biofilm covering the rocks on the bottom of the stream functions as a very efficient biological reactor. In the Bay of Quinte, photoreactions appear to be the main mode of degradation.

The disappearance rate of the substituted benzothiazoles were much more variable than those of the chlorophenols. The results may indicate that 2(methylthio)-benzothiazole (MMBT) and its oxygen containing derivatives are produced in the stream by non-chromatographable precursors. The route of formation of the oxygen-containing MMBT derivatives is still unknown. Degradation studies of benzothiazoles, sulfenamides and of MMBT failed to produce these compounds.

Samples from the Qu'Appelle, Saskatchewan, system were analyzed for chlorophenols and part of this system contains significant levels of pentachloro — and related phenols.

Photodegradation studies of dissolved humics were carried out and superoxide was found to be a product of the photolysis of aquatic humus. This species may be responsible for a variety of indirect photoreductions of contaminants in natural waters. (Carey, Metcalfe, Fox, Colettta Hart)

**Contaminant Studies in Ponds.** The lampricide 3-trifluoromethyl-4-nitrophenol (TFM), was added to three lined, sedimented ponds to determine the fate of this chemical and its effect on the benthos of quiescent waters. In two ponds, technical grade TFM was applied and in the third, TFM purified from the commercial formulation. The environmental rate of the disappearance of commercial grade and purified TFM was 0.070 mg/day. Appreciable concentrations of TFM were measured in the sediment for two weeks following treatment, but concentrations diminished after that time. Trace amounts of TFM were detected in the sediment 117 days following treatment. The water and sediment samples were analyzed for known decomposition products of TFM but no measureable quantities were detected.

The disappearance of the N,N-dimethylamine formulation of 2,4-D in four ponds best followed first-order kinetics with a rate constant of 0.039 mg L<sup>-1</sup> day<sup>-1</sup>. The plot for the concentration of 2,4-D for the ester formulation exhibited two distinct patterns, the first resulting from the dissolution of the 2,4-D from the clay pellets into the water column. This was followed by a gradual decrease in the 2,4-D concentration. This decrease followed first-order kinetics, with a rate constant of 0.41 mg L<sup>-1</sup> day<sup>-1</sup>.

To compare results with an actual field application of 2,4-D, sampling surveys were conducted in Buckhorn Lake. A May 1983 survey of Buckhorn Lake sediment cores showed the presence of 2,4-D in all samples. Concentrations ranged from about 10 ppb in mid-lake to 840 ppb in one of the treated areas. The 2,4-D was found distributed throughout the sediment column (up to 50 cm depths).

Surface sediment samples were collected in the same locations in September 1983. The 2,4-D concentrations in all of these samples were much lower than the May values

suggesting that high degradation rates may have removed most of the new 2,4-D inputs from the summer applications. (Scott, Nagy, Carey, Hart)

## ORGANICS PROPERTIES SECTION

The objective of this Section is to determine the chemical and physical characteristics of toxic substances which govern their effects and pathways in aquatic systems. Field investigations are carried out to determine the distribution of certain contaminants, of contaminant-degrading microorganisms and to identify new contaminants and their sources. In the laboratory, experimental measurements of water/sediment and water/octanol partition coefficients, of bioaccumulation and depuration rates, and of the toxic effects of contaminants, are carried out.

**Structure-Activity Research.** A Workshop on Quantitative Structure-Activity Relationships (QSAR) in Environmental Toxicology was organized at McMaster University, Hamilton, 16 to 18 August, 1983. This workshop was attended by speakers from overseas, the United States, and Canada.

The toxicities of selected chlorophenols to five strains of yeasts as model eukaryotic organisms were investigated in detail. Quantitative measurements showed the sensitivity to such contaminants to increase in the order: *Saccharomyces* sp., *Pichia* sp., *Torulopsis* sp., *Rhodotorula* sp., *Rhodotorula rubra*. The toxicities of the various chlorophenol (P's) were found to increase in the order: Phenol 4-Cl-P; 2,4-Cl<sub>2</sub>-P; Cl<sub>5</sub>-P; 2,4,5-Cl<sub>3</sub>-P.

From largely theoretical work on the comparison of linear and power curve regression analyses of several sets of congeners, it is suggested that the increased chlorine substitution of aromatic and heterocyclic parent com-

pounds, such as benzene, aniline, pyridine, and diphenyl results in declining increases of the octanol/water partition coefficients. The partition coefficients of the chloro congeners follow the general equation

$$\log P_N = (N + 1)^b \cdot \log P_0$$

where N is the number of chlorine substituents,  $\log P_0$  the partition coefficient of the parent compound and b is a constant specific for each set of congeners. The parameters  $\log P_0$  and b are also correlated with each other by the equation

$$b = z \cdot \log P_0^y$$

where z and y are the same constants for all sets. Together, the two equations allow the quick estimation of the partition coefficient of any congener from the known value of another. This ability is of special importance for compounds with 4 logP, where experimental values are difficult to obtain. (Kaiser, Ribo, Kwasniewska, Liu)

**Niagara River Research.** Water samples from 95 stations in Lake Ontario and 16 stations in the lower Niagara River were analyzed for volatile halocarbons and carbon disulfide. The following contaminants were observed at many stations with their lake-wide means and standard deviations: trichlorofluoro-methane (Freon 11), 249 882 ng·L<sup>-1</sup>; methylene chloride, 572±1826 ng·L<sup>-1</sup>; chloroform, 18±92 ng·L<sup>-1</sup> (Figure 2); bromodichloromethane, 3±9 ng·L<sup>-1</sup>; and tetrachloroethylene, 9±65 ng·L<sup>-1</sup>. Six compounds were observed in virtually all Niagara River samples and were traceable into the lake. Both industrialized and urban areas, such as Toronto, Hamilton, and the Niagara River, as well as comparatively small tributaries, such as Twelve Mile, Eighteen Mile, Oak Orchard Creeks, Black River, and the Welland Canal, appear to be sources for several of the observed contaminants.

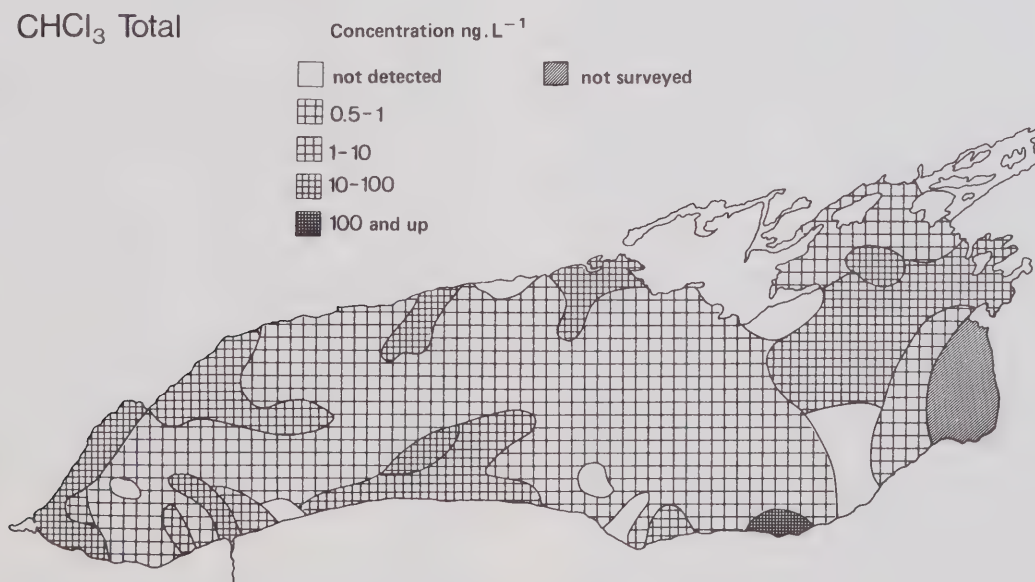


Figure 2 Total chloroform concentrations in Lake Ontario water.



Surveys of selected volatile contaminants in water of the Welland River, a tributary of the Niagara River, show high levels of carbon disulfide, methylene chloride, and chloroform immediately below two industrial outfalls. Downstream from these point sources, a rapid decline in the contaminant concentration is noted due to dilution, degradation and/or volatilization of the compounds. The concentrations of the volatile contaminants are several orders of magnitude lower than those at which acute toxic effects on biota are observed. Studies were also completed on trihalomethanes from chlorination of water and dihaloacetonitriles from drinking water treatment. The effect of humics on natural water acidity, and the potential buffering capacity of lake sediments was investigated as an adjunct to the acid rain research program.

Because of the importance of the Niagara River as a source of chlorinated organic contaminants to Lake Ontario, a sediment core near the mouth of the river was analyzed in detail for organics and radionuclides to study historical trends<sup>4</sup>. Peak discharges of many chlorinated chemicals such as chlorobenzenes to Lake Ontario from the river occurred in the 1960's and are significantly lower today. A study of macroinvertebrates living in bottom sediments near the river mouth showed that they accumulated many of the chlorinated organics that were present in the contaminated sediments.

When rainbow trout were exposed to water contaminated with chlorobenzenes, CB's, they bioconcentrated the CB's from the water. The bioconcentration factor, BCF, (fish conc./water conc.) varied from about 800 for dichlorobenzenes to 13,000 for pentachlorobenzene and was closely related to the chemical's octanol/water partition coefficient. A prediction of CB concentrations in field populations of rainbow trout from Lake Ontario, based on laboratory BCF's and measured Lake Ontario concentrations was, in good agreement with the observed residues for most CB's. The half-lives of individual PCB congeners in rainbow trout showed marked differences — the higher the degree of PCB chlorination, the longer the half-life.

The zonation of aquatic macrophytes, particularly *Typha* and *Sagittaria* sp. and associated periphyton communities, were investigated in relation to industrial point source discharges to the Welland River, Ontario. Severe reductions of macrophyte species densities and macrophyte and periphyton diversity were found immediately below the outfalls with distinct recovery zones in the downstream part. Normal macrophyte and periphyton density and diversity occurred at sites approximately 1.6 km below the outfall. (Kaiser, Comba, Oliver, Nicol)

**Biodegradation of Organic Contaminants.** Commercial PCB formulations, MMBT, aniline and Marlon A were systematically investigated for their biodegradation behaviour and fate. This study resulted in the development of a biological process for the treatment of wastewater containing PCB and the discovery that naturally-occurring humic substances enhance biodegradation of aquatic contaminants.

The toxicity of various halogenated phenols was investigated and the data indicate that the positions of chlorine substituents in the chlorophenols and the octanol/water partition coefficient affect their toxicity. The toxicity of chlorobenzenes to microorganisms was also assessed at the enzyme level and the results indicated the mechanism of chlorobenzenes' biotoxicity is primarily due to their ability to uncouple the oxidative phosphorylation process.

A study has been undertaken to learn the mechanism whereby the biochemical reactions carried out by microorganisms interact with other processes to degrade polychlorinated biphenyls (PCBs) or to effectively remove them from the environment. Many PCBs are converted by bacteria to bright yellow products. These may be further degraded by light, so that a combination of biochemical and photochemical reactions is more effective in destroying these contaminants than either type of reaction alone.

PCB metabolites may undergo conversion by dark colored insoluble materials resembling natural humic substances. It was found that this reaction proceeds spontaneously, i.e., once the metabolites have been formed their further transformation no longer requires the presence of microorganisms. This type of reaction is especially evident with Aroclor 1221 which contains appreciable amounts of biphenyl. The evidence suggests that a substance called catechol produced by the metabolism of biphenyl is co-polymerized with one or more of the yellow metabolites from chlorinated biphenyl to form the insoluble product. (Liu, Baxter, Thomson)

**Analytical Research.** An improved analytical headspace method is described for the quantitative determination of volatile contaminants in water. Detection limits at the 1.0 ng·L<sup>-1</sup> level or better can be achieved for carbon tetrachloride using a suitable capillary column gas chromatograph and electron capture detector. The method is also applicable to the analyses of haloforms and associated halomethanes and haloethanes in drinking water or quantitation of low ppt concentrations in ground or surface waters. This headspace technique is simple, inexpensive, easily applied to field conditions and well suited for cryogenic capillary column chromatography. (Kaiser, Comba)

## INORGANICS SECTION

The objective of this section is to determine the persistence and fate of inorganic and organometallic contaminants in aquatic ecosystems.

**Fate of Tributyltin in Aquatic Environments.** Tributyltin is a pesticide which is extensively used in lumber preservation as a slimicide in cooling towers, and as an antifouling agent in boat paint. It is very toxic to aquatic life. The goal of this study is to determine its persistence and fate in aquatic ecosystems.

Tributyltin and its degradation products, dibutyltin, butyltin, and inorganic tin, are extracted from water or sediment and analyzed by combined gas chromatography/atomic absorption spectrophotometry. Tributyltin appears to be moderately stable chemically; the rate-limiting step of degradation is sunlight photolysis in natural water, with a half-life of at least three months. It is, however, degraded by algae, with a half-life of four weeks at 20°C. Further experiments are under way on adsorption to sediment, bacterial degradation and transformation, and uptake and metabolism by trout, as well as a survey of butyltin occurrence in water and sediment across Canada. (Maguire, Tkacz)

**Determination of Alkylleads and Alkyltins in Aquatic Environments.** Dialkyllead and trialkyllead compounds which have been historically difficult to analyze were for the first time quantitatively extracted by the use of a chelating agent, sodium diethyldithiocarbamate. After butylation to

the tetrasubstituted form, the alkyllead species are analyzed by the GC-AAS method. A GC-AAS chromatogram of the ten alkyllead species is shown in Figure 3.

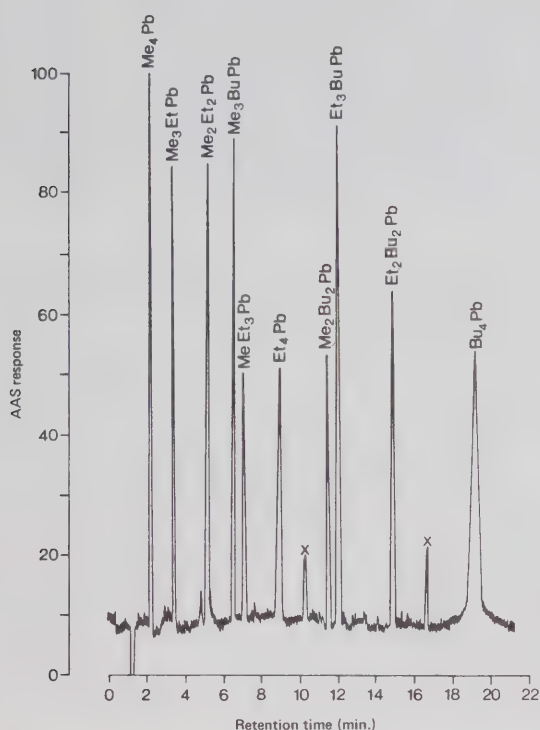


Figure 3 Gas chromatography-atomic absorption spectrometry of five tetraalkyllead compounds (10 ng each); four butyle derivatives of dialkyl- and trialkyllead (8 ng each) and Pb (11) (15 ng). x - unidentified lead compounds.

A survey of the occurrence of methyltin species in the aquatic environment reveals that significant concentrations of methyltin compounds were present in harbours and heavily-industrialized areas associated with organotin usage. The source of methyltin compounds is likely due to the methylation of inorganic tin and the degradation products of other organotins (such as butyltin) of anthropogenic origin. The toxicity of the alkyltin compounds has been found to be related to the chain length of the organic group and the degree of substitution. Diethyllead and triethyllead compounds were for the first time found in fish, sediment, macrophytes and water in the St. Lawrence River off Maitland.

Isolates from four genera of freshwater green algae have been found capable of methylating inorganic arsenic compounds to the various methylarsenic acids under natural conditions. Such methylation by green algae constitutes an additional source for the formation and cycling of organo-arsenic compounds in freshwater ecosystems. (Chau, Bengert)

**Metal and Metalloid Speciation and Bioavailability.** A bioassay was developed using natural phytoplankton populations and sediment elutriate from the Great Lakes. This bioassay was applied to different types of sediment from Great Lakes' harbours and depositional basins. Changes in the phytoplankton community were induced by synergistic effects of nutrient/metals and metals/organic compounds.

Contaminants distributions in the Niagara River/Lake Ontario system indicated the Niagara River as a major source of contaminants found in Lake Ontario sediments. Statistical analyses were carried out on three data sets for organics and metal concentrations in Niagara River sediment.

High concentrations of mercury and arsenic were found in sediments collected from Shubenacadie River headwater lakes of Nova Scotia. Sampling of suspended solids and water indicated a transport of arsenic and mercury by suspended matter. Correlation of gold and mercury concentrations in lake sediments suggested that the mercury contamination originated from the amalgamation process used for gold refining during the past mining activities in the area. (Mudroch, Kokotich)

**Chemical Forms and Availability of Elements of Environmental Importance in the Great Lakes.** Sequential chemical extractions have been done on suspended particulate matter and surficial sediments from the Niagara River-Western Lake Ontario and Detroit River-Western Lake Erie systems. For example, for seven samples collected weekly in the summer of 1982 at Niagara-on-the-Lake, the concentrations of potentially readily-available forms of Cd exceed the Ontario guidelines for open-water disposal of sediments contaminated with this element. For phosphorus, these forms are present in concentrations ranging from 52-460  $\mu\text{g g}^{-1}$ . Total P in Great Lakes sediments are generally 1000-1600  $\mu\text{g g}^{-1}$ . The geochemical mobility of Zn is also quite high and for this data set, the concentration range is 40-120  $\mu\text{g g}^{-1}$  for potentially-available forms.

For surface waters, the measurement of dissolved metal forms is more relevant to assessing potential availability to plankton. In a vertical profile of dissolved Zn at an offshore station (100 m depth) in Lake Ontario, concentrations ranged from 0.22-1.88  $\mu\text{g g}^{-1}$ . The profile showed evidence of release of Zn by sedimenting plankton or fecal pellets and at the 98 m depth a maximum concentration likely caused by resuspension and mixing of pore waters. (Lum, Kokotich)

## RADIONUCLIDES SECTION

The major objective of this Section is to investigate the behaviour of both naturally-occurring and artificially-produced radio nuclides in aquatic ecosystems. Studies include the determination of pathways of radionuclides discharged to lakes, the measurement of levels of these radionuclides in water, biota, and sediments, the application of predictive models for the dispersion of radionuclides into surface waters, and the development of methods for the determination of these radionuclides.

### Levels of Fallout Radionuclides in the Great Lakes Waters.

The levels of  $^{144}\text{Ce}$ ,  $^{137}\text{Cs}$ ,  $^{125}\text{Sb}$ , and  $^{90}\text{Sr}$  in the open waters of the Great Lakes — measured over the period 1973-81 — were found to be very low. The data indicate that the concentrations of all these radionuclides have decreased with time. The measured dose equivalent commitments (0.19 mrem/yr in 1973; 0.10 mrem/yr in 1981) are well within the Canada/US Great Lakes Water Quality Agreement's water quality objective for radioactivity (1 mrem/yr). (Joshi, Platford, Livermore)

**Uranium-Series Radionuclides in Langley Bay, Lake Athabasca (Saskatchewan) Ecosystem.** Levels of these radionuclides in sediments, waters and fish samples are be-



ing determined with the view of determining aquatic pathways of naturally-occurring radionuclides and impact of the abandoned Gunnar uranium mine tailings. The newly developed technique of low-energy gamma-ray spectrometry (Figure 4) is being applied. Preliminary results indicate elevated levels of  $^{210}\text{Pb}$  and  $^{226}\text{Ra}$  in Langley Bay sediments in the immediate vicinity of the tailings pile (1557 and 1519 vs. ambient levels of about 20 and 2 pCi/g respectively). (Joshi, Platford, Livermore)

**Pathways of  $^{226}\text{Ra}$  from Port Granby Radioactive Waste Management Site to Lake Ontario.** Investigations have continued into the groundwater leaching of  $^{226}\text{Ra}$  from the site. A two-dimensional finite element method has been used to simulate groundwater flow patterns along several cross-sections through the site. The groundwater divide indicates that all of the recharging water is flowing to the deeper formations and discharging to Lake Ontario. Contaminant plumes for  $^{226}\text{Ra}$ , U, and  $\text{NO}_3^-$  have been delineated. (Platford, Joshi, FitzGerald)

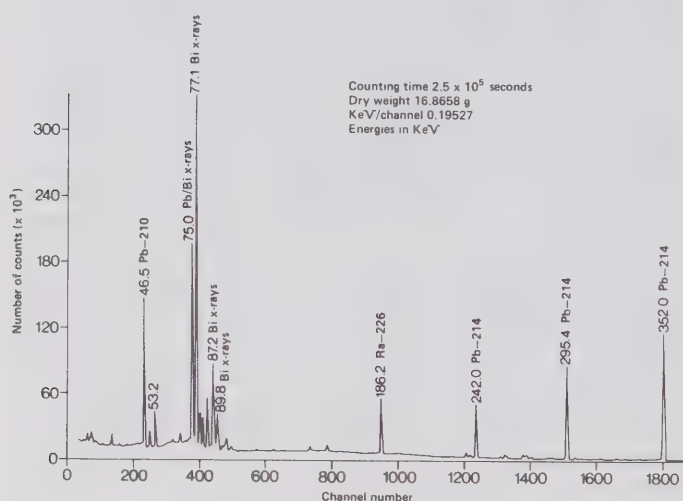


Figure 4 Low energy gamma ray spectrum of Langley Bay sediment sample.

**Radionuclide Pathways in the Niagara River/Lake Ontario.** The possible introduction of transuranics into Lake Ontario from a shut-down nuclear reprocessing plant at West Valley, N.Y., via Cattaraugus Creek/Lake Erie/Niagara River is being investigated. Analytical procedures required for this study have been completed and are currently being used to determine the concentrations of  $^{239,240}\text{Pu}$ ,  $^{241}\text{Am}$ , and isotopic U in sediment cores from 5 locations in Lake Ontario. Levels of  $^{210}\text{Pb}$ ,  $^{226}\text{Ra}$ , isotopic Th, and gamma-emitting nuclear fission products in cores are also being measured. (Joshi, Livermore)

## ACID DEPOSITION SECTION

The objective of research projects conducted by the Acid Deposition Section is to quantify and understand the hydrogeochemical response of acid-sensitive basins to the deposition of air pollutants. Two projects are underway, both utilizing the remote Turkey Lakes Watershed (TLW) as the field study-site. The first study employs calculation of mass balance(s) in the TLW in order to define the most im-

portant geochemical mechanisms controlling the "dose response" relationship for this basin, while the second study is focused on determining the factors or processes controlling the short-term acidification which is associated with spring snowmelt.

The TLW is an undeveloped, hydrologically-calibrated basin (area = 10.5 km<sup>2</sup>) located 50 km north of Sault Ste Marie, Ontario. It is completely forested (mixed hardwood) and contains a chain of 5 lake basins which exhibit a range of geochemical sensitivity and response to acidic deposition. For example, mean lake alkalinity increases from 0.04 to 0.19 meq L<sup>-1</sup> from the headwater to the lowest lake in the chain. Basin geology and geochemistry have been described.

**Geochemical Mass Balances in a Calibrated Watershed.** A June to May "water-year" has been selected for calculation of the mass budgets, and chemical data for two complete years (81-82, 82-83) have been collected, edited, and stored in the computerized national water quality data base (NAQUADAT) for streams and lakes. Stream hydrology has been measured in cooperation with the Water Survey of Canada and flow data are available through 1982. Atmospheric inputs to the watershed are measured. All the necessary meteorological and physical data required for determination of lake evaporation have been collected and evaporation calculated for 1981 and 1982. The first important component of the lake mass balances (e.g., stream loading) is being calculated using a recently developed computer program which automatically accesses the intermittent NAQUADAT and continuous (e.g., daily) hydrology data records. (Jeffries, Semkin, Neureuther, Langlade, Jones)

**Snowmelt and Acid Shock.** The accumulation and loss of ionic pollutants in the snowpack and the effect of snowmelt on surface water chemistry in 1981 and 1982 was studied in the TLW. The contaminants stored in the snowpack were rapidly and preferentially (with respect to water) removed at the beginning of the melting period (Figure 5). The extremely dilute residual snowpack remaining after the initial ion loss still contained over half of the water.

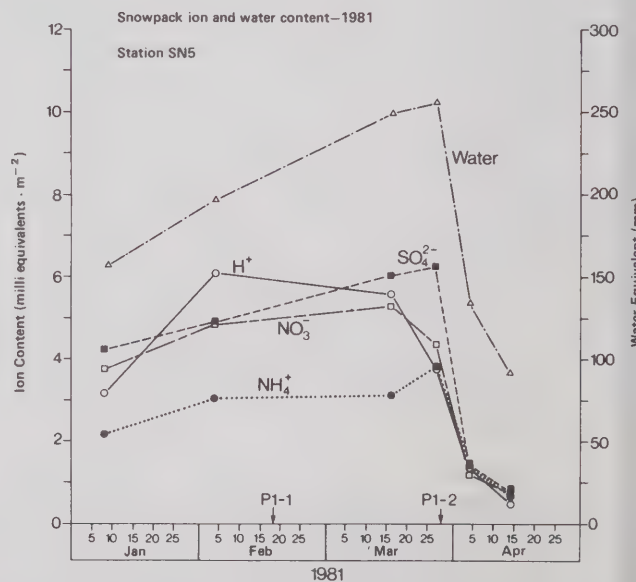


Figure 5 Hydrogen ion,  $\text{SO}_4^{2-}$ ,  $\text{NO}_3^-$ ,  $\text{NH}_4^+$  (meq·m<sup>-2</sup>), and water (mm) content of snowpack at station SN5 from January to April 1981. Dates of important rainfall events are indicated on the horizontal axis.

In response to snowmelt, stream waters exhibited a pH depression and decreases in the concentration of alkalinity and basic cations (Figure 6). The magnitude of pH depression was related to the rate of melting and runoff, being greater in 1981 when the melt period was influenced by continuously warm air temperatures and occasionally heavy rainfall. Only minor variations in  $\text{SO}_4^{2-}$  and  $\text{NO}_3^-$  concentrations were observed. These results are different than those observed in Scandinavia and probably reflect the interaction of the deeper, generally unfrozen soils present in the TLW with runoff waters prior to their appearance in the streams and lakes. (Jeffries, Semkin, English)

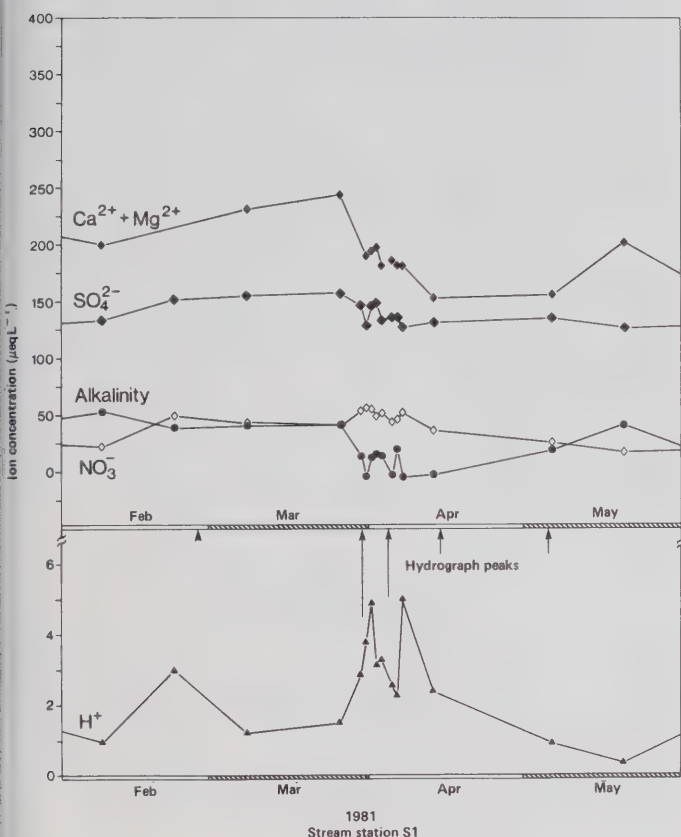


Figure 6 Variation in the concentration ( $\mu\text{eq L}^{-1}$ ) of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{SO}_4^{2-}$ , Alkalinity,  $\text{NO}_3^-$ , and  $\text{H}^+$  at stream station S1 from February to May 1981. Note that the scale for  $\text{H}^+$  is different from the rest. Dates and relative size of the hydrograph peaks are also shown.

## STAFF LIST

Chief — Dr. R.J. Allan  
Secretary — Mrs. E.M. Kerr  
Administrative Officer — Mr. F. Boyd

### Organics-Pathways Section

Head, Dr. J.H. Carey photodegradation of organic contaminants

#### Researchers

Mr. M.E. Fox persistent organic contaminants in aquatic ecosystems  
Mrs. J.L. Metcalfe biological fate of contaminants  
Dr. E. Nagy fate and effects of herbicides  
Dr. W.M.J. Strachan organic contaminants in aquatic ecosystems, especially rain

#### Technical Staff

Miss L. Coletta  
Mr. J.H. Hart

### Organic-Properties Section

Head, Dr. K.L.E. Kaiser structure-activity correlations of organic contaminants

#### Researchers

Dr. R.M. Baxter biochemistry and degradation products of PCBs  
Mrs. K. Kwasniewska biodegradation of organic contaminants and toxicity to microorganisms  
Dr. D.L.S. Liu biodegradation of organic contaminants  
Dr. B.G. Oliver sources of aquatic organic contaminants, water chlorination by products

#### Post Doctoral Fellow

Dr. J.M. Ribo structure-activity correlations of organic contaminants

#### Technical Staff

Mr. M.E. Comba  
Mrs. K.D. Nicol  
Mrs. K. Thomson

### Inorganics Section

Head, Dr. R.J. Maguire aquatic fate of organometallics

#### Researchers

Dr. Y.K. Chau chemical and biological processes of organo-metallics in the aquatic environment; metal speciation and toxicity  
Dr. K.R. Lum chemical forms of trace metals and geochemistry of particulate matter  
Mrs. A. Mudroch chemical forms of trace metals and geochemistry of particulate matter



Technical Staff  
Mr. G.A. Bengert  
Mr. R.J. Tkacz  
Miss E. Kokotich

Acid Deposition Section  
Head, Dr. D.S. Jeffries      geochemical processes controlling lake acidification; metal geochemistry

Researcher  
Mr. R.G. Semkin      geochemical processes controlling lake acidification

Post Doctoral Fellow  
Dr. M. English      snow chemistry

Technical Staff  
Miss M.D. Jones  
Mr. J. Longlade  
Mr. R. Neureuther

Radionuclides Section  
Head, Dr. S.R. Joshi      aquatic pathways of radionuclides

Researcher  
Dr. R.F. Platford      physical chemistry of radionuclides

Technical Staff  
Mr. J.A. FitzGerald  
Mrs. S.A. Thompson

R.J. Maguire  
Environmental Monitoring of Forest Insect Control Committee  
NRC Environmental Secretariat Panel on Organotins  
ECA Chemical Evaluation Committee

Y.K. Chau  
NRC Environmental Secretariat Panel on Organotins  
NSERC Environmental Toxicology Panel  
Standards Council of Canada

K.L.E. Kaiser  
IJC-SAB Task Force on Non-Phosphate Detergents

D.S. Liu  
Standards Council of Canada  
ASTM Oxygen Uptake Group  
UN-FAO Marine Fouling Group

B.F. Scott  
International Standards Organization  
DOE Ontario Region Environmental Emergency Team  
AGRAD Working Group on Fate of Oil

E. Nagy  
AGRAD Working Group on Fate of Oil

## COMMITTEE MEMBERSHIP

R.J. Allan  
Canada/Ontario English-Wabigoon Mercury Study — Co-Chairman  
Editor-in-Chief, "Water Pollution Research Journal of Canada"  
GLWQA Toxic Contaminants Committee  
Algoma Watershed Acid Rain Steering Committee

A. Mudroch  
Canada/US Niagara River Study Committee

W.M.J. Strachan  
GLWQA Toxic Contaminants Committee  
OECD Chemical Testing Program  
GLWQA Aquatic Ecosystem Committee — Chairman  
DOE/NHW Toxic Chemical Committee  
ECA Chemical Evaluation Committee

D.S. Jeffries  
Algoma Watershed Acid Rain Steering Committee

## PUBLICATIONS

*Allan, R.J., A. Mudroch* and M. Munawar (Eds.) 1983. The Niagara River-Lake Ontario Pollution Problem. Special Issue. J. Great Lakes Research, 9:(2) 109-340.

*Baker, M.D., W.E. Inness, C.I. Mayfield, P.T.S. Wong and Y.K. Chau* 1983. Effect of pH on the Methylation of Mercury and Arsenic by Sediment Microorganisms. Environ. Techn. Lett., 4: 89-100.

*Baker, M.D., Y.K. Chau* and C.I. Mayfield 1983. Methylation of Arsenic by Freshwater Green Algae. Can. J. Fish. Aquat. Sci., 40: 1254-1257.

*Baxter, R.M.* and D.A. Sutherland 1983. Biochemical and Phytochemical Processes in the Degradation of Chlorinated Biphenyls. Environ. Sci. and Technol. (In press).

*Baxter, R.M.* and *J.H. Carey* 1983. Evidence for the Photochemical Generation of Superoxide Ion in Humic Waters. Nature, 306: 575-576.

*Carey, J.H., M.E. Fox, J.L. Metcalfe*, B. Brownlee, P. Mason and W.H. Yerey 1983. The Fate and Effects of Contaminants in Canaqaque Creek. 1. Stream Ecology and Identity of Major Contaminants. IWD Scientific Series 135.

*Carey, J.H., M.E. Fox, B.F. Scott* and *E. Nagy* 1982. Studies on the Degradation and Fate of TFM in the Environment. A report to the Great Lakes Fishery Commission.

*Carey, J.H., M.E. Fox*, B.G. Brownlee, *J.L. Metcalfe* and *R.F. Platford* 1983. Disappearance Kinetics of 2,4 — and 3,4-dichlorophenol in a Fluvial System. Can. J. Physics & Pharmacol., (In press).

*Chau, Y.K.*, P.T.S. Wong and O. Kramar 1983. The Determination of Dialkyllead, Trialkyllead, Tetraalkyllead and Lead (II) Ions in Water by Chelation/Extraction and Gas Chromatography/Atomic Absorption Spectrometry. Anal. Chim. Acta, 146: 211-217.

*Chau, Y.K.*, P.T.S. Wong, *G.A. Bengert* and J.L. Dunn 1983. Determination of Dialkyllead, Trialkyllead, Tetraalkyllead and Lead (II) Compounds in Sediment and Biological Samples. Anal. Chem., (In press).

- Chau, Y.K.** and **P.T.S. Wong** 1983. Direct Speciation Analysis of Molecular and Ionic Organometals. IN: G.G. Leppard (Ed.) Trace Element Speciation in Surface Waters and its Ecological Implications. Plenum Publ. Corp., p. 87-103.
- Chau, Y.K.** and **P.T.S. Wong** 1983. Organolead in the Aquatic Environment. IN: P. Grandjean (Ed.) Biological Effects of Organolead Compounds. CRC Press, (In press).
- Chau, Y.K.** and **P.T.S. Wong** 1982. Determination of Methyltin (VI) and tin (IV) Species in Water by Gas Chromatography-Atomic Absorption Spectrometry. Anal. Chem. 54: 246-249.
- Comba, M.E.** and **K.L.E. Kaiser** 1983. Determination of Volatile Contaminants at the Ng.L-1 Levels in Water by Capillary Gas Chromatography with Electron Capture Detection. Intern. J. Environ. Anal. Chem., 16: 17-31.
- Dickman, M., C. Prescott and **K.L.E. Kaiser** 1983. Variations in the Aquatic Vegetation of the Welland River (Ontario, Canada) Above and Below an Industrial Waste Discharge. J. Great Lakes Res., 9: 317-325.
- Durham, R.W.** and **S.R. Joshi** 1983. Dose Equivalent Commitments and Levels of Fallout Radionuclides in the Open Waters of the Great Lakes 1973-1981. Environ. Monitor. & Assessment, (In press).
- Durham, R.W.** and **B.G. Oliver** 1983. History of Lake Ontario Contamination from the Niagara River by Sediment Radiodating and Chlorinated Hydrocarbon Analysis. J. Great Lakes Res., 9(2) 160-168.
- Edgar, D. and **K.R. Lum** 1983. Zeeman Effect Electrothermal Atomic Absorption Spectrophotometry with Matrix Modification for the Determination of Arsenic in Urine. Intern. J. Environ. Anal. Chem., 16: 219-226.
- Fox, M.E., J.H. Carey** and **B.G. Oliver** 1983. Compartmental Distribution of Organochlorine Contaminants in the Niagara River and the Western Basin of Lake Ontario. J. Great Lakes Res., 9(2) 287-294.
- Fox, M.E.** and **S.R. Joshi** 1983. The Fate of Pentachlorophenol in the Bay of Quinte, Lake Ontario. J. Great Lakes Res., (In press).
- Fraser, J.L. and **K.R. Lum** 1982. Availability of Elements of Environmental Importance in Incinerated Sludge Ash. Environ. Sci. Technol., 17: 52-54.
- Hashimoto, Y., K. Tokura, K. Ozaki and **W.M.J. Strachan** 1982. A Comparison of Water Solubilities by the Flask and Micro-column Methods. Chemosphere, 11: 991-1001.
- Hodson, P.V., D.M. Whittle, P.T.S. Wong, U. Borgmann, R.L. Thomas, **Y.K. Chau**, J.O. Nriagu and D.J. Hallett 1983. Lead Contamination of the Great Lakes and its Potential Effects on Aquatic Biota. IN: J.O. Nriagu (Ed.) Adv. in Environ. Tech. Wiley & Sons. (In press).
- Hodson, P.V., P.T.S. Wong, **Y.K. Chau**, O. Kramar and D.M. Whittle 1983. Occurrence of Alkyllead Compounds in the Aquatic Environment. Proc. 11th Aquatic Toxicity Workshop, (In press).
- Hushon, J.M., A.W. Klein, **W.M.J. Strachan** and F. Schmidt-Bleek 1983. Use of OECD Premarket Data Exposure Analysis for New Chemicals. Chemosphere, 12: 887-910.
- Jeffries, D.F.** 1983. Lake Evaporation and Energy Budgets in the Turkey Lakes Watershed (1980-81). Turkey Lakes Watershed Unpublished Report Series No. TLW-83-04, 57 p.
- Jeffries, D.F.** and **R.G. Semkin** 1983a. Data Report: Major Ion Composition of Lake Outflows and Major Streams in the Turkey Lakes Watershed (January 1980-1982). Turkey Lakes Watershed Unpublished Report Series No. TLW-83-05, 30 p.
- Jeffries, D.F.** and **R.G. Semkin** 1983b. Changes in Snowpack, Stream, and Lake Chemistry During Snowmelt in the Turkey Lakes Watershed. Turkey Lakes Watershed Unpublished Report Series No. TLW-83-10, 24 p.
- Jeffries, D.S., R.G. Semkin, R. Neureuther** and **M.D. Jones** 1983. Data Report: Major Ion Composition of Lake Waters in the Turkey Lakes Watershed (January 1980-May 1982). Turkey Lakes Watershed Unpublished Report Series No. TLW-83-11, 9 p.
- Jeffries, D.S.** 1983. Lake Evaporation and Energy Budgets in the Turkey Lakes Watershed (1980-81). Turkey Lakes Watershed Unpublished Report Series No. TLW-83-04, 57 p.
- Jeffries, D.S.** and **R.G. Semkin** 1983a. Data Report: Major Ion Composition of Lake Outflows and Major Streams in the Turkey Lakes Watershed (January 1980-1982). Turkey Lakes Watershed Unpublished Report Series No. TLW-83-05, 30 p.
- Jeffries, D.S.** and **R.G. Semkin** 1983b. Changes in Snowpack, Stream, and Lake Chemistry during Snowmelt in the Turkey Lakes Watershed. Turkey Lakes Watershed Unpublished Report Series No. TLW-83-10, 24 p.
- Joshi, S.R.** and **M.E. Fox** 1983. The <sup>210</sup>Pb and <sup>137</sup>Cs Profiles in Sediment Cores from the Bay of Quinte, Lake Ontario. J. Radioanal. Chem., (In press).
- Kaiser, K.L.E.** 1983. A Non-linear Function for the Approximation of Octanol/Water Partition Coefficients of Aromatic Compounds with Multiple Chlorine Substitution. Chemosphere 12: 1159-1167.
- Kaiser, K.L.E.** and **M.E. Comba** 1983. Volatile Contaminants in the Welland River Watershed. J. Great Lakes Res., 9(2) 274-280.
- Kaiser, K.L.E., M.E. Comba** and **H. Huneault** 1983. Volatile Halocarbon Contaminants in the Niagara River and in Lake Ontario. J. Great Lakes Res., 9(2) 212-223.
- Kaminsky, R., **K.L.E. Kaiser** and R.A. Hites 1983. Fates of Organic Compounds from Niagara Falls Dumpsites in Lake Ontario. J. Great Lakes Res., 9(2) 183-189.
- Kwasniewska, K., D. Liu** and **W.M.J. Strachan** 1981. The Relative Biological Toxicity Effectiveness of Chemicals Toward Microorganisms. IN: D.D. Hemphill (Ed.) Proceedings of Conf. on Trace Substances in Environmental Health — XIV. University of Missouri, p. 470-477.
- Kwasniewska, K.** 1982. The Degradation of Pentachlorophenol (PCP) by a Fungus of *Fusarium* sp. IN: D.D. Hemphill (Ed.) Proceedings of Conf. on Trace Substances in Environmental Health — XV. University of Missouri, p. 392-398.
- Kwasniewska, K.** and **K.L.E. Kaiser** 1983. Toxicities of Selected Phenols to Fermentative and Oxidative Yeasts. Bull. Environ. Contam. Toxicol., 31: 188-194.
- Kwasniewska, K.** and **K.L.E. Kaiser** 1983. Toxicity of Selected Chloroanilines to Four Strains of Yeasts. IN: K.L.E. Kaiser (Ed.) QSAR in Environmental Toxicology. D. Reidel Publ., Dordrecht, Holland (In press).
- Liu, D.** and **K. Kwasniewska** 1981. Movement of Sewage Microorganisms in Soils. IN: D.D. Hemphill (Ed.) Proceedings of Conf. on Trace Substances in Environmental Health — XIV. University of Missouri, p. 464-469.
- Liu, D.** 1982. Assessment of Continuous Biodegradation of Commercial PCB Formulations. Bull. Environ. Contam. Toxicol., 29: 200-207.
- Liu, D.** 1982. The Effect of Sewage Sludge Land Disposal on the Microbiological Quality of Groundwater. Water Research, 16: 957-961.
- Liu, D., K. Thomson** and **K.L.E. Kaiser** 1982. Quantitative Structure-Toxicity Relationship of Halogenated Phenols on Bacteria. Bull. Environ. Contam. Toxicol., 29: 130-136.
- Liu, D.** 1983. Study on Biodegradability of Aniline and Marlon A. IN: T.A. Oxley and S. Barry (Ed.) Biodeterioration. John Wiley & Sons, p. 169-175.
- Liu, D.** 1983. Resazurin Reduction Method for Activated Sludge Process Control. Environ. Sci. Technol., 17: 407-411.
- Liu, D.** and **K. Thomson** 1983. Toxicity Assessment of Chlorobenzenes Using Bacteria. Bull. Environ. Contam. Toxicol., 31: 105-111.
- Liu, D.** and **J.H. Carey** 1983. Fulvic-acid Enhanced Biodegradation of Aquatic Contaminants. Bull. Environ. Contam. Toxicol., 31: 203-207.
- Lum, K.R.** and D. Edgar 1983. The Determination of Arsenic by Flame AAS using the Zeeman Effect and its Application to the Analysis of Sediment Extracts. Intern. J. Environ. Anal. Chem., 15: 141-148.
- Lum, K.R.** and D. Edgar 1983. Determination of the Chemical Forms of Cadmium and Silver in Sediments by Zeeman Effect Flame Atomic-Absorption Spectrometry. Analyst, 108: 918-924.
- Lum, K.R.** and W.A.M. Bhupsingh 1983. The Leaching of Some Elements of Environmental Importance in Blast Furnace and Steel-Making Slags. NWRI Contribution 83-18.
- Lum, K.R.** and J.K. Leslie 1983. Dissolved and Particulate Metal Chemistry of the Central and Eastern Basins of Lake Erie. Sci. Total Environ., 30: 99-109.
- Lum, K.R., D. Naranjit, B. Radziuk** and T. Thomassen 1983. A Universal Microcomputer Interface for the Rapid Acquisition of Data from Atomic Absorption Spectrometers. Anal. Chim. Acta, 155: 183-189.
- Maguire, R.J., J.H. Carey** and **E.J. Hale** 1983. Degradation of the Tri-n-butyltin Species in Water. J. Agric. Food Chem., 31: 1060-1065.
- Maguire, R.J., P.T.S. Wong** and J.S. Rhamey 1983. Accumulation and Metabolism of Tri-n-butyltin Cation by a Green Alga, *Ankistrodesmus falcatus*. Can. J. Fish. Aquat. Sci., (In press).
- Maguire, R.J., K.W. Kuntz** and E.J. Hale 1983. Chlorinated Hydrocarbons in the Surface Microlayer of the Niagara River. J. Great Lakes Res., 9: 281-186.
- Maguire, R.J., Y.K. Chau, G.A. Bengert, E.J. Hale, P.T.S. Wong** and O. Kramar 1982. Occurrence of Organotin Compounds in Ontario Lakes and Rivers. Environ. Sci. Technol. 16: 698-702.
- Maguire, R.J.** 1983. Analysis, Occurrence and Persistence of Organotin Compounds in the Environment. NWRI Report No. 8325.
- Maguire, R.J.** 1983. Butyltin Compounds and Inorganic Tin in Sediments in Ontario. Environ. Sci. Technol., (In press).
- Maguire, R.J.** and **R.J. Tkacz** 1983. Analysis of Butyltin Compounds by Gas Chromatography. Comparison of Flame Photometric and Atomic Absorption Spectrophotometric Detectors. J. Chromatogr., 268: 99-101.
- Maguire, R.J.** and **E.J. Hale** 1982. Bis(tri-n-butyltin)oxide (TBIO) in Water: Hydrolysis and Volatilization. NWRI Unpublished Report.



**Manning, P.G., K.R. Lum** and T. Birchall 1983. Forms of Iron, Phosphorus and Trace Metal Ions in a Layered Sediment Core from Lake Ontario. *Can. Mineralogist*, 21: 121-128.

**Metcalfe, J.L., M.E. Fox** and **J.H. Carey** 1984. Aquatic Leeches (*Hirundinea*) as Bio-indicators of Organic Chemical Contaminants in Freshwater Ecosystems. *Chemosphere*, 13: 143-150.

**Mudroch, A.** 1983. Investigation of Contamination of Durham Cruise Marina, Oshawa, Ontario. NWRI Unpublished Report.

**Mudroch, A.** 1983. Distribution of Major Elements and Metals in Sediment Cores from the Western Basin of Lake Ontario. *J. Great Lakes Res.*, 9:(2) 125-133.

**Mudroch, A.** and S. Litten 1982. Standardization of Contaminants Data for Niagara River Sediment. Report to the US-Canada Niagara River Toxics Committee.

Munawar, M., **A. Mudroch**, I.F. Munawar and R.L. Thomas 1983. The Impact of Sediment-associated Contaminants from the Niagara River Mouth on Various Size Assemblages of Phytoplankton. *J. Great Lakes Res.*, 9:(2) 303-319.

**Nagy, E., P. Mudroch, A. Mudroch** and R.L. Thomas 1983. Hydrocarbons in the Surficial Sediments of Lakes St. Clair, Erie and Ontario. *Environ. Geology*, (In press).

**Nagy, E., B.F. Scott** and **J. Hart** 1983. The Fate of Oil and Oil-dispersant Mixtures in Freshwater Ponds. *Sci. of Tot. Env.*, (In press).

**Niimi, A.J.** and **B.G. Oliver** 1983. Biological Half-lives of Polychlorinated Biphenyl (PCB) Congeners in Whole Fish and Muscle of Rainbow Trout (*Salmo gairdneri*). *Can. J. Fish. Aquat. Sci.*, 40: 1388-1394.

**Oliver, B.G.** and **K.D. Bothen** 1982. Extraction and Cleanup Procedures for Measuring Chlorobenzenes in Sediments and Fish by Capillary Gas Chromatography. *Int. J. Environ. Anal. Chem.*, 12: 131-139.

**Oliver, B.G.** and J.R.M. Kelso 1983. A Role for Sediments in Retarding the Acidification of Headwater Lakes. *Water, Air, and Soil Pollut.*, 20: 379-389.

**Oliver, B.G.** and **K.D. Nicol** 1982. Gas Chromatographic Determination of Chlorobenzenes and Other Chlorinated Hydrocarbons in Environmental Samples Using Fused Silica Capillary Columns. *Chromatographia*, 16: 336-340.

**Oliver, B.G.** and **K.D. Bothen** 1982. Chlorobenzenes in Sediments, Water and Selected Fish from Lakes Superior, Huron, Erie and Ontario. *Environ. Sci. Technol.*, 16: 532-536.

**Oliver, B.G.** and **K.D. Nicol** 1983. Comment on Chlorobenzenes in Sediments, Water and Selected Fish from Lakes Superior, Huron Erie and Ontario. *Environ. Sci. Technol.*, 17: 504-505.

**Oliver, B.G.** and **A.J. Niimi** 1983. Bioconcentration of Chlorobenzenes from Water by Rainbow Trout: Correlations with Partition Coefficients and Environmental Residues. *Environ. Sci. Technol.*, 17: 287-291.

**Oliver, B.G.** and E.M. Thurman 1983. The Influence of Aquatic Humic Substances Properties on Trihalomethane Potential. Book Chapter in *Water Chlorination: Environmental Impact and Health Effects*, Vol. 4. Ann Arbor Science Publishers, p. 231-241.

**Oliver, B.G.** 1983. Dihaloacetonitriles in Drinking Water: Algae and Fulvic Acid as Precursors. *Environ. Sci. Technol.*, 17: 80-83.

**Oliver, B.G.,** E.M. Thurman and R.L. Malcolm 1983. The Contribution of Humic Substances to the Acidity of Colored Natural Waters. *Geochim. Cosmochim. Acta*, 47: 2031-2035.

Onuska, F.I., **A. Mudroch** and K.A. Terry 1983. Identification and Determination of Trace Organic Substances in Sediment Cores from Western Basin of Lake Ontario. *J. Great Lakes Res.*, 9:(2) 169-182.

**Platford, R.F.** 1983. The Octanol-Water Partitioning of Some Hydrophobic and Hydrophilic Compounds. *Chemosphere*, 12: 1107-1111.

**Platford, R.F.** 1983. Some Thermodynamic Properties of Metillic Acid. *J. Chem. Eng. Data* (In press).

Ribo, J.M. and **KK.L.E. Kaiser** 1983. Effects of Selected Chemicals to Photoluminescent Bacteria and their Correlations with Acute and Sublethal Effects on other Organisms. *Chemosphere*, 12: 1421-1442.

**Scott, B.F., E. Nagy**, B.J. Dutka, W.D. Taylor, V. Glooschenko, P.J. Wade and **J. Hart** 1983. The Fate and Impact of Oil and Oil-dispersant Mixtures in Freshwater Pond Ecosystems: Introduction. *Sci. of the Total Environ.* (In press).

**Scott, B.F.** and V. Glooschenko 1983. Impact of Oil and Oil-dispersant Mixtures on the Flora and Water Chemistry Parameters in Freshwater Ponds. *Sci. of the Total Environ.* (In press).

**Scott, B.F.,** B.J. Dutka, J.P. Sherry, V. Glooschenko, P.J. Wade, W.D. Taylor, **E. Nagy** and N.B. Snow 1983. Impact of Oil and Oil-dispersant Mixtures on Freshwater Pond Ecosystems. IWD Scientific Series No. 130.

**Scott, B.F.,** P.J. Wade and W.D. Taylor 1983. Impact of Oil and Oil-dispersant Mixtures on the Fauna of Freshwater Ponds. *Sci. of the Total Environ.* (In press).

**Scott, B.F.,** M.D. Dickman and P. Hayes 1983. Effect of 2,4-D on Natural Phytoplankton Systems in Association with *Myriophyllum spicatum*. *Ver. Internat. Verein Limnol.* (Submitted).

**Scott, B.F.,** W.D. Taylor, D.S. Painter, M.D. Dickman and **E. Nagy** 1984. Systems used to Study the Fate and Impact of Contaminants. NWRI Unpublished Report.

**Semkin, R.G.** and **D.S. Jeffries** 1983. Rock Chemistry in the Turkey Lakes Watershed. Turkey Lakes Watershed Unpublished Report Series No. TLW-83-03, 9 p.

**Strachan, W.M.J.** and **H. Huneault** 1983. Evaluation of an Organic Automated Rain Sampler. *Environ. Canada. Inland Waters Directorate Techn. Bull.* No. 128.

**Strachan, W.M.J.** and C.J. Edwards 1983. Organic Pollutants in Lake Ontario. IN: J.O. Nriagu and M.S. Simmons (Ed.) *Toxic Contaminants in the Great Lakes*. J. Wiley, N.Y. (In press).

**Strachan, W.M.J.,** W.A. Glooschenko and **R.J. Maguire** 1982. Environmental Impact and Significance of Pesticides, Chapter 1. IN: A.S.Y. Chau and B.K. Afghan (Ed.) *Analysis of Pesticides in Water — Vol. 1. Significance, Principles, Techniques and Chemistry of Pesticides*. CRC Press, Boca Raton.

Wong, P.T.S., **Y.K. Chau**, O. Kramar and **G.A. Bengert** 1982. Structure-toxicity Relationship of Tin Compounds on Algae. *Can. J. Fish. Aquat. Sci.*, 39: 483-488.

Wong, P.T.S., and **Y.K. Chau** 1982. Physiological and Biochemical Responses of Several Freshwater Algae to a Mixture of Metals. *Chemosphere*, 11: 367-376.

Wong, P.T.S. **Y.K. Chau** and D. Patel 1983. The Use of Algal Batch and Continuous Culture Techniques in Metal Toxicity Study. IN: J.O. Nriagu (Ed.) *Aquatic Toxicology*. John Wiley & Sons, p. 449-466.

## ANALYTICAL METHODS DIVISION

The Analytical Methods Division is responsible for research and development of analytical methodologies for chemical and microbiological pollutants in the aquatic environment, for conducting national and international quality assurance programs and for providing centralized computing service to all components of CCIW. The Division undertakes national and regional research programs in analytical chemistry, microbiology and quality assurance and transfers completed technology to the national and regional laboratories of IWD and other clients.

The staff of the Division maintains close contact with scientists in other Canadian federal departments, provincial governments, U.S. federal and state agencies, and with universities. In some cases collaborative studies are undertaken. The Division strongly supports the work of the International Joint Commission, the International Standards Organization, American Society for Testing and Materials, Federal Interdepartmental Committee on Pesticides, and Association of Official Analytical Chemists, by membership on committees and task groups.

The Analytical Methods Division is divided into four Sections covering analytical chemistry research, quality assurance and methods adaptation, microbiology and computer services.

### ANALYTICAL CHEMISTRY RESEARCH SECTION

The Analytical Chemistry Research Section (ACRS) is engaged in advanced methodology and instrumentation research. The main objective is to provide analytical methods to IWD regional laboratories and other agencies within the federal government. The techniques currently employed include atomic and molecular spectroscopy, high resolution gas chromatography, GC/MS, high pressure liquid chromatography, radioimmunoassay, electrochemistry and flow-injection analysis. Analytical methods are developed for water, sediment, soil, fish, aquatic plant materials, waste waters, solid wastes, road runoff, leachates, etc. The sensitivity of the methods developed within ACRS vary depending upon the need of the end user and sample matrix.

**Heavy Metals.** A modified method was developed for the determination of chromium in water by atomic absorption spectroscopy. In this work it was shown that the problems of the existing method were due to the chromium not being completely oxidized to  $\text{Cr}^{\text{VI}}$  in the presence of the organics in the sample and hence not being complexed and extracted. The preferred oxidant was found to be potassium persulfate. This completely oxidizes the chromium, destroys the organics and can be thermally decomposed after the oxidation is complete.

Hydride generation and inductively coupled argon plasma emission spectroscopy has been used for the determination of tin in environmental samples. The chemistry for the optimum production of stannane has been determined and a study made of the ways to physically separate the stannane. This has resulted in a very sensitive method, having a detection limit of  $0.01 \mu\text{g L}^{-1}$  Sn in water.

The method for the digestion of fish tissue for the determination of arsenic and selenium has been developed that does not use perchloric acid. It has been shown that a nitric-sulfuric acid mixture can be used for this digestion, eliminating the hazards and the need for special facilities in using perchloric acid. (Goulden)

**Inorganic Parameters.** The development of the dynamic mode of electrochemical sensor operation continued with the incorporation of pH, chloride and water hardness sensors into a previously developed system for dissolved oxygen, conductivity and temperature. An immersible micro-processor based digital system suitable for *in situ* operation was designed and tested. Mathematical equations for computing and correcting experimental data as well as for calibration of the system have been derived.

A conductometric acid-base titration method for the determination of alkalinity and acidity of water samples has been developed. It has been shown that the conductometric titration is superior to the potentiometric titration in terms of detection limits ( $0.1 \text{ mg L}^{-1}$ ), sampling rate (30 s/sample) and precision ( $\pm 2\%$ ). No interfering effects from other constituents were observed. This technique is ideally suited to low buffered waters and precipitation samples and hence is extremely useful in the acid rain program.

A method for the determination of acidity and alkalinity utilizing flow-injection analysis has also been developed. The basis of the method is that the injection of the reagent results in a change of the conductivity. This change is registered in the form of peaks and related to the concentration of alkalinity or acidity in the sample. Linear calibration curves down to  $0.1 \text{ mg L}^{-1} \text{CaCO}_3$  were obtained with a relative standard deviation of 5%. Ten mL of the sample is sufficient to produce five replicate peaks at a sampling rate of up to 30 samples/hour. (Sekerka)

**Organic Parameters.** A method for the determination of phenols in a variety of environmental samples with improved preconcentration, cleanup and quantitation steps has been developed. It involves extraction of the sample in acidic medium using toluene or methylenechloride. The initial fractionation of the extract is achieved by preparative gel permeation chromatography using a styrogel column. Further cleanup involving extraction with sodium triphosphate is followed by acidic back extraction and quantitative analysis by HPLC or derivative GC. The spike recoveries ranged from 80-93%.

A method for the analysis for polychlorinated dibenzo-p-dioxin (PCDD) was developed which included soxhlet or liquid/liquid extraction, preparative GLC using styrogel, tri-sodiumphosphate extraction and alumina and carbon fibre cleanup steps. Quantitative analysis was carried out using high resolution GC-low resolution mass spectrometry. The method was validated for water, fish, wood preservative, technical phenols and related samples. The recoveries of selected PCDDs ranged from 56 to 85%.

An improved method for analysis of chlorophyll pigments was developed. It includes improved extraction, optimization of the conditions to minimize hydrolysis and decomposition of chlorophyll, improved preservation techniques and HPLC with fluorescence detector for quantitation of individual pigments at ultratrace levels. The method was compared with conventional spectrophotometric method and found to be superior.

Considerable advances have been made with narrow bore capillary column gas chromatography. Theoretical considerations and experimental results demonstrate the ability to increase the speed of analysis and/or the resolving power for such compounds as PCB's and toxaphene. These columns can be used without modification to commercial chromatographs. Splitless and on-column injectors were evaluated for use in multi-residue analysis of PCBs. It was found that for quantitation of wide boiling



range mixtures at picogram levels, on-column injection is the only technique which yields satisfactory results. This method for PCBs allows the determination of individual isomers, homologous groups and total PCBs as low as 0.1 mg/kg in sediment samples. Chromatograms of toxaphene residues are complex and some means of establishing similarities in residue profiles are needed. Three methods for quantitation of toxaphene are being evaluated.

- A. Narrow-bore wall coated open tubular (WCOT) gas chromatography with Electron Capture Detection (ECD) can provide fingerprints suitable for estimation, but lacks specificity. The detection limit is 0.5 mg/kg.
- B. GC-MS selected ion monitoring using electron impact induced ionization gives the detection limit of 1.1 mg/kg.
- C. Electron impact mode — SIM in medium resolution produces 1 µg/kg limit of detection. (*Onuska*)

Radioimmunoassay (RIA) techniques have been proposed for rapid and inexpensive screening of large numbers of environmental samples. A radioimmunoassay laboratory has been established and preliminary research undertaken to develop an RIA procedure for polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. 1-N (5-iodovaleramide) — 3,7,8 trichlorodibenzo-p-dioxin was synthesized, labelled with <sup>125</sup>I and evaluated. The chemistry of the labelling reaction was subsequently examined and an improved procedure proposed. (*Sherry*)

## QUALITY ASSURANCE AND METHODS SECTION

The work of the Section comprises three main areas: quality assurance; development of certified reference materials (CRMs) and reference materials (RMs); and methods development (Figure 1). The quality assurance programs involve the design and implementation of several types of quality control (QC) studies as well as investigations of sample homogeneity and stability. These programs assess the analytical performance and ensure the generation of reliable, valid and compatible analytical data on a regional, national and international basis. Development of CRMs and RMs are essential to increase the effectiveness of these quality control studies. Reference materials and CRMs are also required for methodology development, for

the evaluation of precision and accuracy of laboratory data and for QC studies for the selection of contract laboratories.

The methods development program involves applied research to develop or validate analytical methods for water, sediments and biota. The Section also provides expert advice to the operational laboratories of the Water Quality Branch.

**Quality Assurance (QA).** Three new programs have been initiated this year:

- (a) Long Range Transport of Air Pollutants (LRTAP) QA Program,
- (b) Prairie Provinces Water Board (PPWB) QA Program, and
- (c) Dredging QA Program.

**(a) LRTAP QA Program:** This program was initiated in 1982 in response to the concern about data compatibility and quality among laboratories generating data for the LRTAP program. Each year, 3 multi-sample QC studies for some 40 inorganic parameters in water are designed and sent out to about 60 Canadian and a few U.S. laboratories. (*Aspila*)

**(b) Prairie Provinces Water Board QA Program:** This program, initiated in September 1982 is designed for assessing and improving the compatibility of water quality data generated by the Federal and the Alberta, Saskatchewan and Manitoba Provincial laboratories. Twelve studies, each involving some 40 inorganic parameters, are conducted per year. Extensive computer programming and several computer files are being generated to meet the objectives of the program. This program is an extension of the existing interregional QC studies for the national and regional Water Quality Branch Laboratories. (*Alkema*)

**(c) Dredging QA Program:** Under the auspices of the International Joint Commission, a new QA program for organic and inorganic parameters specifically designed for dredging programs in the Great Lake Basin, was initiated in September 1983. There are four key components in this program: design and conduct of intercomparison studies; development of specific certified reference samples; design of suitable computer programs to provide capability information and short and long term laboratory performance; development of QA criteria for analytical contracts for dredging programs. (*Lee*)

In addition to these three new activities the Section actively continued its ongoing national and international quality assurance studies.

The National Q.C. Study involves over 100 federal, provincial, university and private laboratories and includes both inorganic and organic parameters in water and sediment. These studies serve to assess methodology and data of the Water Quality Branch laboratories by comparison with peer laboratories, establish laboratory performance of the Water Quality Branch and private laboratories to permit selection of private laboratories for contract analysis and provide additional data for certification of reference materials. This year an organics study for pesticides in sediment was conducted. (*Lee*)

In addition to the Dredging QA program, the Section has also provided a lead role in QA for the International Joint Commission's Great Lakes International Surveillance Program. International intercomparison studies for phosphorus in effluents, trace metals in water and organics in fish have been conducted this year. A QC study for chlorinated pesticides was designed and conducted under the auspices of the Federal Interdepartmental Committee on Pesticides.

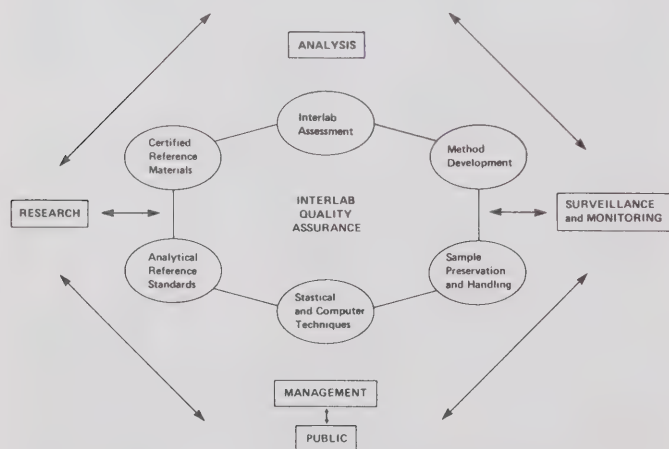


Figure 1 Diagram showing the components and interrelationship of interlaboratory quality assurance.

Research and development of certified reference materials continued in support of the quality assurance programs. The certification of three sediment CRMs for three different levels of Arsenic, Selenium and Mercury was completed this year. Two sediment CRMs for polynuclear aromatic hydrocarbons (PAHs) have also been prepared. These PAH CRMs are the first of this type available. (Lee)

**Sample Stability and Preservation.** The centralization of the Water Quality Branch laboratories will involve longer time periods between sample collection and sample analysis. Since a major consideration in the reliability of any laboratory measurement is that of sample integrity, technological needs for the sampling process and handling prior to analysis must be addressed. A study of currently used preservation techniques was initiated in 1983 for all inorganic and organic parameters routinely analysed by the National Water Quality Laboratory. Phase one of this study, major ions and nutrients, will be largely completed by mid 1984. (Chau)

**Methods Development.** A multi-residue method for the analysis of 15 chlorophenols in water was developed and a multiclass method for acid and neutral herbicides in sediment and in water is at its final stage of development. An evaluation of current methodologies for sulfate determination (Technicon colorimetric and Ion Chromatographic) was completed as part of the LRTAP program. Highly coloured waters should only be analysed for sulfate by ion chromatography. (Cheam)

## MICROBIOLOGY LABORATORIES SECTION

The Microbiology Laboratories Section has two main program areas. One is to develop and evaluate microbiological methodologies and criteria for monitoring, assessing and maintaining water quality from the standpoint of chemical contaminants and microbiological hazards. The other is to conduct environmental research into the effects of pollutants on the population of microorganisms in the aquatic ecosystem.

As most of the microbiological expertise of the Department of the Environment is consolidated within the Microbiology Laboratories Section directional guidance for the research is based on:

1. perception of the needs of NWRI and the Department of the Environment to fulfill their mandates;
2. requests for specific environmental microbiological information from the various Inland Waters Directorate regions across Canada;
3. priorities of the IJC Water Quality Board and the Long Range Transport of Airborne Pollutants program, and
4. national and international contacts who inform us of present or upcoming microbiological problems in their areas or countries.

During the past year the Microbiology Laboratories Section staff concentrated their efforts on three main areas:

1. The distribution patterns of *Legionella* organisms in Canadian natural and domestic waters and *Legionella* growth studies.
2. Comparison studies of various microbial toxicity screening procedures and holding the First International Symposium on Toxicity Testing Using Bacteria.
3. The effects of acid rain (LRTAP) on microbial populations and physiology.

Coupled with these scientific efforts Microbiology Laboratories staff also participated in a variety of joint research and support studies such as, electron microscope studies on the effects of acid stress on bacterial morphology, ASTM round robin studies on methods evaluation, provision of microbiological data to the IJC on potential problem areas in Lake Superior and the evaluation and revision of nitrogen cycle enumeration methodology for our methods manual "Methods for the Microbiological Analyses of Waters, Wastewaters and Sediments". Over 700 of these methods manuals have been distributed by request, to virtually every country in the world performing environmental microbiology research.

**Legionella Studies.** In cooperation with the Department of Health and Welfare, a study is being carried out to ascertain if *Legionella* organisms can be isolated from public and industrial building water distribution systems in major cities across Canada. As part of this study an intensive investigation of rivers and lakes in the three Maritime provinces, Prince Edward Island, Nova Scotia and New Brunswick was carried out during the summer using a mobile laboratory. From the preliminary data collected this year, it would appear that the *Legionella* organisms can be readily found in potable and cooling tower water systems. Laboratory studies were also performed to elucidate the survival characteristics of *Legionella*. these studies centred around longevity of the organism in fresh and salt water, soil, on porous and non porous material, in ice and under the stress of sunlight. (Dutka)

**Toxicity Screening.** One of the highlights of this project was the holding of the First International Symposium on Toxicity Testing Using Bacteria on May 17-19, 1983 at the Canada Centre for Inland Waters. Thirty-nine papers were presented by delegates from 11 countries, from Russia in the East to Japan in the West. Based on the very positive response to this first Symposium, it was decided to hold similar symposia every two years. (The next will be in Banff, May 6-10, 1985).

This year saw the completion of much of our basic comparison studies of various microbial toxicity screening tests using pure and mixed chemical solutions ie. Microtox, *Spirillum volutans*, synthetic activated sludge, *Pseudomonas fluorescens* density inhibition etc. All of the information from those studies has now been documented in various research journals and in-house publications.

The evaluation of a new and novel toxicity screening procedure was initiated this year. The microbial electrode for toxicity screening is based on the use of an oxygen probe onto which a pure culture of bacteria is attached by means of a membrane filter. This procedure is being evaluated using our standard set of pure and mixed chemicals and then it, along with the other procedures evaluated in our laboratories will be field tested next year using sewage effluent and river water samples. (Dutka)

**Effects of Acid Stress on Microbes.** As part of the LRTAP studies Microbiology Laboratories Section staff studied the effects of acid precipitation on aquatic microorganisms. Several water and sediment cores from 8 lakes receiving acid precipitation near Sudbury, Ontario were collected and examined for total, respiring and aerobic heterotrophic bacterial populations. These studies were complemented with laboratory experiments using laboratory fermenters to illustrate the effects of acid stress on microbial activity and morphology.



Substrate/populations	pH 7.2		pH 4.0	
	Time	Time	Time	Time
	0hr	3hrs	0hr	3hrs

1. Glucose

Total bacteria	$9.1 \times 10^9$	$9.5 \times 10^9$	$2.8 \times 10^7$	$3.2 \times 10^8$
Resp. bacteria	$1.3 \times 10^9$	$1.5 \times 10^9$	ND	ND

2. Glutamic acid

Total bacteria	$7.3 \times 10^9$	$7.4 \times 10^9$	$1.9 \times 10^8$	$2.7 \times 10^8$
Resp. bacteria	$0.7 \times 10^9$	$0.7 \times 10^9$	ND	ND

3. Sodium acetate

Total bacteria	$8.3 \times 10^9$	$8.5 \times 10^9$	$2.3 \times 10^8$	$2.7 \times 10^8$
Resp. bacteria	$2.2 \times 10^9$	$9.7 \times 10^9$	ND	ND

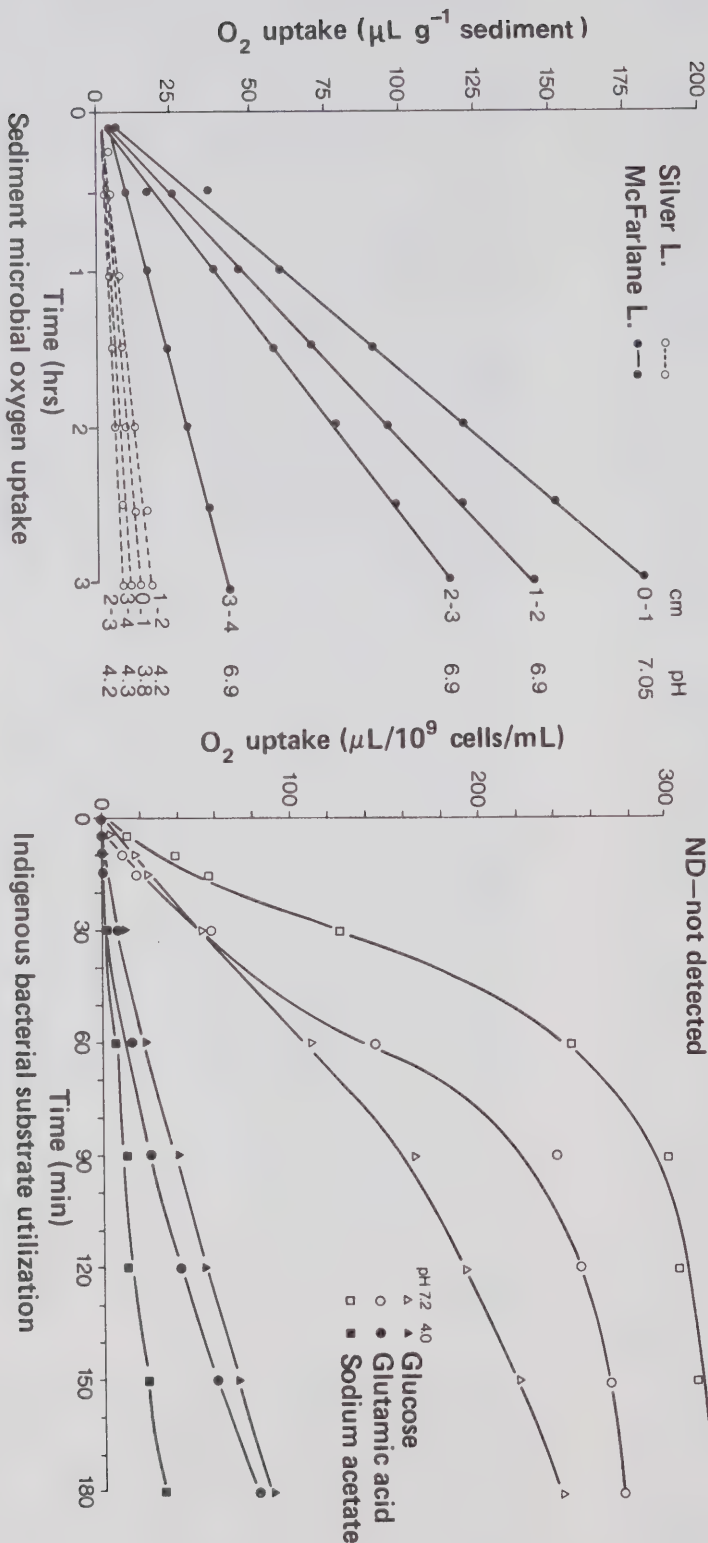


Figure 2 Microbial activity from acid stressed and non-acid stressed lakes.

Data indicated that a strong relationship existed between lake acidification and bacterial activity. pH values below 5.5 appear to be critical for bacterial respiration and multiplication. In acid stressed lakes (pH 3.8) the sediment respiration was 15-20% of that in a normal lake (pH 7.2) (Figure 2). Associated with this, a strong correlation was demonstrated between pH and total organic matter content. Bacterial ultrastructure and cell diversity can also be correlated with a specific level of pH. The retarded metabolic activity in bacteria is attributed to the alteration in the selective permeability of the cell membrane. (Rao)

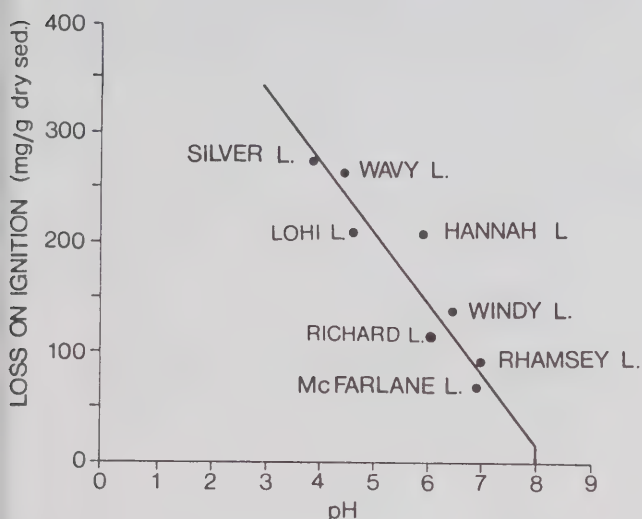


FIGURE 3  
pH AND TOTAL ORGANICS IN LAKE SEDIMENTS

## COMPUTER SERVICES SECTION

The Computer Services Section operates and provides system software support for the large scale scientific computing facilities at the Canada Centre for Inland Waters. Services are provided to all components of the Centre since much of current environmental research is dependent on the availability of adequate computer resources. The Section's work affects many NWRI research programs.

The facilities of the section include a Control Data (CDC) Cyber 171 computer system supporting batch and time-sharing access, a high speed Calcomp plotting system, two minicomputers, and a data entry service.

**Future Requirement Planning.** Since the contract for the currently installed CDC Cyber 171 Sytem will expire in June of 1984, a study team was formed in mid-1982 to evaluate the future computing requirements for CCIW. After polling managers throughout IWD, it was concluded that the scope of services provided by the Section would remain essentially unchanged during the next few years. A technical evaluation team, with members from the Computer Services and Data Management Sections (NWRI) and Computing and Applied Statistics Directorate, was formed for the purpose of evaluating specific computing requirements and assisting the Section in the procurement phase.

**Upgrades and Software Development.** In the spring of 1983, the Section was able to acquire the PDP-16/60 mini-computer which had been leased by Water Quality Branch for the AWQALABS system. This computer was installed to

replace the aging PDP-15 computer which had been in use since 1971. The system software development to support existing PDP-15 applications (time-series data editing, digitizing) was completed in October 1983. Applications development in these areas is being done by the Data Management Section.

Interactive access to magnetic tapes became available on the Cyber 171 system in the fall of 1982. This feature was initially provided on a short-term test basis and was later made permanent as no problems had arisen. Users reaction was extremely favourable. Software to drive an MVI-7 colour graphics terminal with standard Calcomp subroutine calls was written in October 1982. This allowed the display of color graphs and contour maps. The Calcomp contour plotting program was later modified to provide hard copy multicolor maps. (Pulley)

**Operations.** The volume of work handled by the Section has continued to increase. During fiscal year 1982/83, Cyber 171 computer usage increased by 34%. Growth in other areas has been less dramatic, and the demand for card-based services continued to decline.

During FY 1982/83, 113 500 batch jobs and interactive sessions were run on the Cyber 171 system and 2830 hours of central processor time were used. The system was in operation for over 5000 hours and system availability continued to exceed 99%. The estimated value for all services provided to CCIW by the section in FY 1982/83 was in excess of \$1 000 000. (Pulley)

## STAFF LIST

**Chief — Dr. J. Lawrence**  
**Secretary — Mrs. J. Burford**  
**Administrative Officer — Mr. S.C. Smith**

### Analytical Chemistry Research Section

**Head, Dr. I. Sekerka**      electroanalytical chemistry and flow injection analysis

#### Researchers

Dr. P.D. Goulden      automation and atomic spectroscopy  
 Dr. F.I. Onuska      gas chromatography and GC/MS  
 Dr. B.F. Scott      high pressure liquid chromatography, polarography, molecular fluorescence spectrometry

#### Technical Staff

Mr. J.F. Ryan  
 Mr. R.J. Wilkinson  
 Mr. J.R. Lechner  
 Mr. D.H. Anthony  
 Mr. K.A. Terry

### Microbiology Laboratories Section

**Head, Mr. B.J. Dutka**      microbiological methods, toxicity screening

#### Researchers

Dr. S.S. Rao      acid stressed bacteria, lake microbiology  
 Dr. J.P. Sherry      mycology, radioimmunoassay



Technical Staff  
 Mr. A.A. Jurkovic  
 Mr. K.K. Kwan  
 Mr. R. McInnis  
 Mrs. A. Jova  
 Ms. K. Walsh

#### Quality Assurance and Methods Section

Head, Mr. A.S.Y. Chau research and development of CRMS, development of quality assurance programs

#### Researchers

Dr. V. Cheam methods development (inorganic) some quality control studies

Mr. H. Alkema specification generation, inter-regional Q.C., preservation studies

Mr. K.I. Aspila IJC Q.C. program and LRTAP Q.C. studies

Dr. H.B. Lee national and IJC Q.C. (organics), standard reference materials (inorganics), sample storage conditions, methods evaluation

Mrs. Y. Stokker organic method development, some Q.C. studies

#### Technical Staff

Mrs. S. Todd  
 Mr. R. Hong-You

#### Computer Services Section

Head, Mr. H.C. Pulley

Ms. M. Kinder operations supervisor

Mr. B. Malseed computer console operation

Ms. U. Hamilton computer console operator

Ms. P. Moody computer console operator

Ms. J. Foley peripheral and keypunch operator

#### Clean and Hazardous Chemicals Laboratory

Mr. R.J. Wilkinson

#### K.I. Aspila

Data Quality Work Group, IJC Water Quality Programs Committee — Chairman

LRTAP Quality Assurance Subgroup, Federal-Provincial Committee on LRTAP

#### A.S.Y. Chau

Task Group Chairman — D:19 on Water, ASTM General Referee, Committee E, Water Methodology, AOAC

Appointed Member, Quality Assurance Committee, AOAC Coordinator for Water and Sediment, FICP Check Sample Programs, FICP

#### V. Cheam

Analytical Methods Work Group — LRTAP

#### B.J. Dutka

ASTM Subcommittee D19:24 — Chairman

Task Group D19:24:01.19, Legionella — Chairman

Task Group D19:24:06.06, Sulphate reducing bacteria — Chairman

Task Group D19:24:06.07, Toxicity Tests; D19:24:08.08, Mutagen Tests; D19:24:08.09, Epifluorescence Microscopy; D19:24:08.18, Heterotrophic Bacteria

ASTM D19 Executive Committee

Joint Task Group, Section 907, APHA Standard Methods

CAC/ISO/TC147 — Chairman

Canada ISO/TC147/SC4, Microbiology — Chairman

IST/TC147/SC4/WG9, Membranes — Chairman and International Secretary

IST/TC147/SC5/WG1, Mutagens — Chairman and International Secretary

Canadian Task Group Chairman — Aerobic bacteria ISO/TC147/SC4/WG1

International Symposia on Toxicity Testing Using Bacteria Committee — Co-Chairman

Associate Editor, "Journal of Great Lakes Research"

Editorial Board, WHO "Water Quality Bulletin"

Microbial Problems Committee of the American Water Works Association

### COMMITTEE MEMBERSHIP

#### B.K. Afghan

Subcommittee 2 on Canadian Advisory Committee on ISO/TC147 — Chairman

Canadian Advisory Committee for Standards Council of Canada

Task Group Chairman for various ASTM task groups: Nutrients in Sediment, Chlorinated Dioxins, Liquid Chromatography and ATP (these task groups form an integral part of ASTM Subcommittees 6, 7 and 24)

#### P.D. Goulden

IWD Committee on Technical Training

#### J. Lawrence

Great Lakes Toxic Chemicals Committee

Analytical Capability Committee

Associate Committee on Scientific Criteria for Environmental Quality

RMCC Quality Assurance Sub-Group — Co-Chairman

**H.B. Lee**  
Associate Referee for Herbicides, Committee E,  
Water Methodology, AOAC  
Associate Referee for Organo-phosphate,  
Committee E, Organo-phosphate, AOAC

**F.I. Onuska**  
Panel Member on PAH in Water, Subcommittee  
on Water of NRCA Associate Committee on  
Scientific Criteria for Environmental Quality  
Advisory and Editorial Board, "High Resolution  
Chromatography and Chromatography Communi-  
cations Journal"  
Pesticides and Toxics Secretariat Legal and  
Metrology Organization Secretariat

**H.C. Pulley**  
VIM (CDC Computer User's Group) Applications  
and Graphics Products Committee

**S.S. Rao**  
ASTM Task Group D19:24:06:09 and D19:24:06:10  
— Chairman  
Advisory Committee, Masters Program,  
Department of Biology, University of Toronto  
(sponsored by Dr. A.P. Zimmerman)

## PUBLICATIONS

**Afghan, B.K.**, T. Bridle and K. Conn. Recent Developments in Identification, Assessment and Control of Industrial Pollutants. Internal Report No. 81-AMD-3-83-BKA.

**Afghan, B.K.** Recent Advances in Quantitative Analysis and Confirmation of Pollutants in the Aquatic Environment. Internal Report No. 80-AMD-3-83-BKA.

**Alkema, H.** Interregional Quality Assurance Studies No. 98-99. Internal Report No. 76-AMD-6-83-HA.

**Alkema, H.** Interregional Quality Assurance Studies No. 101-101. Internal Report No. 82-AMD-3-83-HA.

**Alkema, H.** Prairie Province Water Board Quality Assurance Studies PP No. 1-6. Internal Report No. 84-AMD-6-83-VC.

**Aspila, K.I.** A Report on the Preparation of the IJC Study 44Total P in Sewage Plant Effluents. Internal Report Series 78-AMD-6-83-KA.

**Aspila, K.I., et al.** *Guidelines for In-lab Quality Assurance for LRTAP Projects.*

**Aspila, K.I.** and **S. Todd.** Intercomparison Study L-1, Major Ions, Nutrients and Physical Properties in Water. Internal Report No. 87-AMD-6-83-KA.

**Aspila, K.I.** and **S. Todd.** LRTAP Intercomparison Study L-2, Trace Metals in Water. Internal Report No. 86-AMD-6-83-KA.

**Aspila, K.I.,** R.J. White and J. Clark 1983. Interlaboratory Quality Assurance of the IJC's Great Lakes Monitoring Program. ASTM Special Technical Publication Series (In press).

**Charlton, M.N.** and **S.S. Rao** 1983. Oxygen Depletion in Central and Eastern Lake Erie — Relationship with Bacteria Chlorophyll, POC and Morphometry. J. Great Lakes Research, 9: 3-8.

**Chau, A.S.Y.** 1983. General Referee Report on Water. JAOAC (In press).

**Chau, A.S.Y.** 1983. Recent Advances in the Research and Development of Certified Reference Materials for Environmental Quality Assurance. Proceedings to the 18th Annual Western Canada Seminar for Pesticide Residues. The Analyst (In press).

**Chau, A.S.Y.** 1983. Standard Reference Materials in Environmental Quality Assurance. Water Around the World, Part II, Water Quality Bulletin, 8(1).

**Chau, A.S.Y.** and **J. Lawrence.** Quality Assurance of Environmental Measurement: An Overview. Internal Report No. 88-AMD-6-83-AC.

**Cheam, V.** and **A.S.Y. Chau** 1983. Analytical Reference Materials IV. Development and Certification of the 1st Great Lakes Sediment Reference Materials for As, Se, and Hg. The Analyst (In press).

**Cheam, V.** Interregional Quality Assurance Studies IR No. 96-87. Internal Report No. 71-AMD-5-83-VC.

**Cheam, V.** PPQC Studies Nos. 1,2,3 and 4 — Trace Metals and Major Ions. Internal Report No. 84-AMD-5-83-VC.

**Dutka, B.J.** 1983. Standards for Microbiological Methods or Chaos. ASTM Standardization News, October, 2022 pp.

**Dutka, B.J.** and P. Ewan 1983. First Isolation of *Legionella pneumophila* from the Canadian Great Lakes. J. Great Lakes Research, 9: 130-132.

**Dutka, B.J.,** N. Nyholm and J. Petersen 1983. Comparison of Several Microbiological Toxicity Screening Tests. Water Research, 17: 1363-1368.

**Dutka, B.J.** and **K.K. Kwan** 1983. Environmental Studies of Enteric Bacteria Longevity in Membrane Filter Chambers. Journal of American Water Works Association, 75: 380-382.

**Dutka, B.J.** and **K.K. Kwan** 1983. Microbiological Examination of Lake Erie and Lake Ontario Sediments. Hydrobiologia, 98: 135-145.

**Dutka, B.J.** and **K.K. Kwan** 1982. Application of Four Bacterial Screening Procedures to Assess Changes in the Toxicity of Chemicals in Mixtures. Environment Pollution (Series A), 9: 125-134.

**Dutka, B.J.** and **A. Jova.** Results of the Application of the *Salmonella typhimurium* Microsome Test for Mutagenic Activity on Samples Submitted to the Microbiology Laboratories Section. Internal Report No. 40-AMD-5-82-BJD.

**Dutka, B.J.** Microbiological Laboratories Safety Manual — August 1982.

**Dutka, B.J.** and **K.K. Kwan.** Longevity Studies of Enteric Bacteria Using Membrane Filter Chambers. Internal Report No. 42-AMD-5-82-BJD.

**Dutka, B.J.** and **K.K. Kwan.** Studies on a Synthetic Activated Sludge Toxicity Screening Procedure with Comparison to Three Microbial Toxicity Tests. Internal Report No. 57-AMD-5-82-BJD.

**Dutka, B.J.** and P. Ewan. Isolation of *Legionella pneumophila* from the Canadian Great Lakes. Internal Report No. 31-AMD-5-81-BJD.

Gonnord, M.F., G. Guiochon and **F.I. Onuska** 1983. Narrow Bore Open Tubular Columns for Improvement of Gas Chromatographic Analysis Time. Anal. Chem., vol. 55: 2115-2120.

**Goulden, P.D.** and **D.H.J. Anthony.** Determination of Trace Metals in Environmental Samples by Inductively Coupled Argon Plasma — Atomic Emission Spectrometry. Internal Report No. 51-AMD-3-82-PDG.

**Goulden, P.D.** and **D.H.J. Anthony.** A Modified Method for the Determination of Chromium in Natural Waters. Internal Report No. 59-AMD-3-82-PDG.

**Goulden, P.D.** and **D.H.J. Anthony.** Determination of Tin in Environmental Samples by Hydride Generation. NWRI Contribution No. 83-6.

Hallet, D.J., **F.I. Onuska** and M.E. Comba 1983. Aliphatic and Polyaromatic Components of Weathered and Unweathered Southern Louisiana Crude Oil. Mar. Env. Res., 8: 73-85.

Hallet, D.J., R.J. Norstrom, **F.I. Onuska** and M.E. Comba 1982. Incidence of Chlorinated Benzenes and Chlorinated Ethylenes in Lake Ontario Herring Gulls. Chemosphere, 11(3): 277-285.

Karasek, F.W. and **F.I. Onuska** 1982. Trace Analysis of the Dioxins. Anal. Chem., 54: 309A.

Lean, D.R.S., A.P. Abbott, N.M. Charlton and **S.S. Rao** 1983. Seasonal Phosphate Demand for Lake Erie Plankton. J. Great Lakes Research, 9: 83-91.

**Lee, H.B.** and **A.S.Y. Chau** 1983. Determination of Titluralin, Diallate, Triallate, Atrazine, Barban, Diclofop-Methyl and Benzoylprop Ethyl in Natural Waters at Parts per Trillion Levels. JAOAC, 66: 651.

**Lee, H.B.** and **A.S.Y. Chau** 1983. Analysis of Pesticide Residues by Chemical Derivatization. VI — Analysis of the Ten Acid Herbicides in Sediment. JAOAC, 66: 1023.

**Lee, H.B.** and **A.S.Y. Chau** 1983. Analysis of Pesticide Residues by Chemical Derivatization. VII — Chromatographic Properties of Pentafluorobenzyl Ether Derivatives of 32 Phenols. JAOAC, 66: 1029.

**Lee, H.B.** and **A.S.Y. Chau** 1983. Analysis of 7 Neutral Herbicides in Sediments. JAOAC (In press).

McQueen, D.J., **S.S. Rao** and D.R.S. Lean 1983. Hypolimnetic Aeration: Changes in Bacterial Populations and Oxygen Demand. Arch. Fur. Hydrobiol. (In press).

**Onuska, F.I.,** R.J. Kominar and **K.A. Terry** 1983. Identification and Determination of Polychlorinated Biphenyls Using High Resolution Gas Chromatography. Jour. Chromatography, 279: 111-118.

**Onuska, F.I.,** A. Mudroch and **K.A. Terry** 1983. Identification and Determination of Trace Organic Substances in Sediment Cores from the Western Basin of Lake Ontario. J. Great Lakes Res., 9(2): 169-182.

**Onuska, F.I.,** R.J. Kominar and **K.A. Terry** 1983. An Evaluation of Splitless and On-Column Injection Techniques for the Determination of Priority Micropollutants. J. Chrom. Sci., 21: 512-518.

**Pulley, H.C.** Annual Report. Computer Services Section Support. Fiscal Year 1981-82.

**Pulley, H.C.** EDP Report and Plan 1982-83. Government Report 1982.

**Rao, S.S. and B.J. Dutka** 1983. Influence of Acid Precipitation on Bacterial Population in Lakes. *Hydrobiologia*, 98: 153-157.

**Rao, S.S., A.A. Jurkovic** and J.O. Nriagu 1983. Bacterial Activity in Sediments of Lakes Receiving Acid Precipitation. *Environmental Pollution (Series A)* (In press).

**Rao, S.S., D. Paolini and G.G. Leppard** 1983. Effects of Low pH Stress on the Morphology and Activity of Bacteria from Lakes Receiving Acid Precipitation. *Hydrobiologia* (In press).

**Rao, S.S., L. Bhaskar and A.A. Jurkovic.** Microbiological Studies of Some Watersheds Receiving Acid Precipitation in Canada. Internal Report No. 37-AMD-5-82-SSR.

**Rao, S.S., A.A. Jurkovic** and P. Robson. Effects of Acid Precipitation on Microbial Populations in Northern Ontario Lakes. Internal Report No. 62-AMD-5-81-SSR.

**Rao, S.S. and A.A. Jurkovic.** Summary Observations of Bacteriological Conditions in Lake Ontario (1977-1981 and 1982). Internal Report No. 68-AMD-3-83-SSR.

**Scott, B.F., E. Nagy, B.J. Dutka, J.P. Sherry,** W.D. Taylor, V. Glooschenko, P.J. Wade and J. Hart 1983. The Fate and Impact of Oil and Oil Dispersant Mixtures

on Freshwater Pond Ecosystems: Introduction. *Journal of Environmental Quality* (In press).

**Scott, B.F., B.J. Dutka, J.P. Sherry,** V. Glooschenko, P.J. Wade, W.D. Taylor, E. Nagy, N.B. Snow and D.B. Carlisle 1982. Impact of Oil and Oil Dispersant Mixtures on Freshwater Pond Ecosystems. IWD Scientific Series Report No. 130.

**Sekerka, I. and J.F. Lechner** 1983. The Dynamic Mode of Electrochemical Sensors Operation. *Proc. Int. Meeting on Chem. Sensors*, Japan.

**Sekerka, I. and J.F. Lechner** 1983. Determination of Alkalinity and Acidity of Water Samples by Conductometric Titration. *JAOAC* (In press).

**Sekerka, I. and J.F. Lechner** 1983. Determination of Alkalinity and Acidity by Flow Injection Analysis. *Anal. Letters* (In press).

**Sherry, J.P. and A.A. Qureshi** 1981. Isolation and Enumeration of Fungi using Membrane Filtration. IN: B.J. Dutka (ed.), *Membrane Filtration: Techniques, Applications, and Problems*. Marcel Dekker Inc., New York, p. 189-218.

**Sherry, J.P.** 1983. Impact of Oil and Oil Dispersant Mixtures on Fungi in Freshwater Ponds. *Journal of Environmental Quality* (In press).

**Sherry, J.P.** The Sister Chromated Test. Internal Report No. 43-AMD-5-82-JPS.

**Sherry, J.P.** Mycological Aspects of the Effects of 2,4-D on Natural Freshwater System. Internal Report No. 39-AMD-5-82-JPS.

**Sherry, J.P.** Temporal Distribution of Fungi at a Nearshore Station in Lake Ontario. Internal Report No. 91-AMD-5-83-JPS.



## HYDRAULICS DIVISION

The Hydraulics Division has mandates to undertake research into all aspects of the hydraulics of inland waters and to provide a multi-disciplined engineering capability in design, manufacture and maintenance of special equipment and measuring systems to support other inland water research teams.

National programs are undertaken in applied and basic research related to hydraulic, fluid mechanic, hydrologic, geophysics and geologic processes as they apply to fluvial, lacustrine and man-made environments.

The Hydraulics Division is organized in three research sections and three service sections: Environmental Hydraulics, Shore Processes, Technical Services, Engineering Services, Manufacturing and Technical Development, and Drafting Services. There is also an Office Services Section.

### ENVIRONMENTAL HYDRAULICS SECTION

There are three main areas of research in the Environmental Hydraulics Section: open-channel hydraulics, river ice engineering and urban water resources.

**Flow in Mobile Bed Channels.** Work continued on the development of models for the prediction of transport of water and sediment in alluvial rivers and on the investigations of basic physical relationships which are required for improving theories and models.

Experiments were carried out to investigate the causes of meander formation. It was found that meanders formed even in laminar flows which were free of secondary circulations. Thus the popular hypothesis that turbulence-driven secondary circulation is the cause of meander formation should be abandoned. (*Krishnappan*)

Conditions for the beginning of sediment transport are being investigated, including the critical mean flow velocity, and the effects of sediment density and grain size distribution. An equation for the critical mean flow velocity in terms of flow depth and sediment size has been developed. This equation is convenient for hydraulic design purposes. A review of recent data have identified effects of sediment density on the Shields curve which is generally used to determine the beginning of sediment transport. New experiments are underway to assess the density effects as well as the effects of sediment size distribution. (*Engel*)

**Performance of Bed Load Sampler.** Dimensional analysis was used to express the sampler catch and sampling efficiency of the VUV type bed load sampler in terms of flow condition, sediment properties and sampler geometry. Existing data and new data obtained in a large sediment flume, using a scale model of the half size VUV sampler, were used to examine the effects of the pertinent independent variables whereas the sampling efficiency could be defined in terms of one dimensionless variable. The sampling efficiency was found to vary from 60% to about 30% over the normal operating range. (*Engel*)

The effects of ice covers on the sediment transport and bedforms in rivers have been investigated by laboratory experiments. It was found that sediment transport rate can be significantly reduced by the presence of an ice cover. Velocity and sediment concentration measurements are being used to investigate different methods of calculating the rate of sediment transport in ice-covered rivers. (*Lau*)

The effects of suspended sediments on the velocity distribution as well as the effects of sinuosity and bedform on the friction factor of stream flows have also been investigated. (*Krishnappan*)

A turbulence model has been used to predict the vertical distribution of suspended sediment in two-dimensional, uniform flows with ice covers. A family of curves have been derived, giving the relative concentration as a function of distance from the bottom (Fig. 1). These curves show that the sediment distribution is dependent on the ratio of bed roughness to top-cover roughness and that the sediment concentration is lower than in free surface flows at the same relative height. The turbulence model has been further developed into a three-dimensional model. It uses an algebraic relation to evaluate the Reynolds stresses which are required for the computation of the turbulence driven secondary circulations. The model has been used to predict the secondary circulations in channel flows with various aspect ratios, and is being used to calculate the flow and shear stress distributions in compound channel flows with flood plains. (*Krishnappan*)

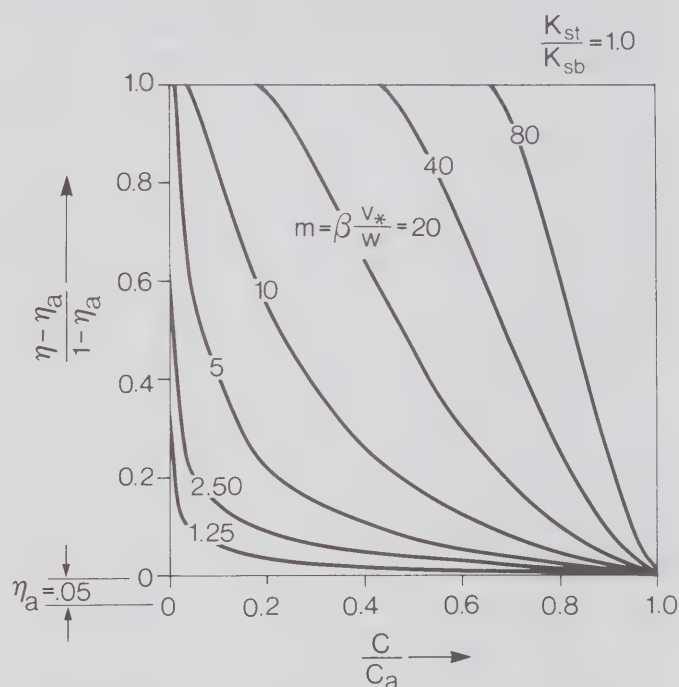


Figure 1. Suspended Sediment Distribution for Flows with Top Covers.

The flow model MOBED which was developed by the Hydraulics Division was used to predict the depths of scour resulting from flow constrictions such as bridge piers, artificial islands, etc. These predictions were compared with the calculations made using a method recommended in the Guide to Bridge Hydraulics. It was found that the method recommended in the guide often could not give accurate predictions. MOBED was also used to predict the degradation of the streambed below the Gardiner Dam in the South Saskatchewan River. The predictions are being compared with those made using HEC6 which is a model developed by the U.S. Army Corp of Engineers. The goal of the study is to evaluate the applicability of HEC6, which is a steady state model, to the unsteady flow conditions which are generally encountered in practice. (*Krishnappan*)



The computer model RIVMIX, which was designed for predicting transverse mixing in natural streams, was documented in a users' manual. The model is suitable for problems such as delineation of "mixing zones" or determination of concentrations from outfalls discharging into rivers. It also is capable of transferring water quality profiles downstream. (Krishnappan, Lau)

The Research Committee of the Hydrotechnical Division, Canadian Society for Civil Engineering initiated several task groups. The Environmental Hydraulics Section played a leading role in the Task Group for River Mixing which has completed a state-of-the-art report, to be published in the Canadian Journal for Civil Engineering. (Lau)

**Ice Jams and Flooding.** The field observation program which was initiated in 1979 was continued, with the emphasis being on collection of quantitative data needed to address deterministic and statistical aspects of river ice breakup and jamming. Freeze up and winter ice conditions were also documented as they have been found to influence the breakup process. Ice observations were carried out for the fourth and fifth years in the lower Thames River and for the third and fourth years in the Upper Grand River. Cooperation with other agencies interested in jamming problems has been expanded. (Beltaos, Wong)

A dimensionless expression for the stage caused by jams in equilibrium was developed. This expression is convenient for practical applications and was obtained by combining ice jam theory with hydraulic resistance considerations. Field documentation for the verification of the expression is continuing. (Beltaos)

A well known and often fearsome event during breakup is the surging ice run that follows the release of a major ice jam. Theoretical analysis has shown that approximate surge calculations can be performed by neglecting the effect of moving ice fragments. Following initial confirmation of this result using a field case study, complete verification was made with detailed laboratory measurements (Fig. 2). (Beltaos, Wong)

Conditions at ice jam toes are largely unknown at present, despite their importance in jam formation and release mechanisms especially in cases of grounding. Laboratory tests were carried out with two different model ice block sizes. These indicated non-laminar seepage flow through the jam voids and are consistent with pertinent dimensionless relationships for flow through porous media. Experiments are now in progress to study possible mechanisms of grounding. (Beltaos, Wong)

To define breakup characteristics and develop forecasting methods, water level records of hydrometric gauges operated by Water Survey of Canada were analyzed. The analysis led to the development of a conceptual model of the breakup process. An important factor facilitating the onset and progress of breakup has been identified as the available water surface width relative to the size of separate ice sheets formed by transverse and longitudinal cracking. This was verified by direct observations in the Thames River and enabled derivation of dimensionless relationships that can partly account for findings in different rivers. However, there remain many unknowns, including the mechanisms of the initial ice cover cracking and the effects of thermal ice deterioration. These processes are now under investigation while the analysis is applied to additional gauges each year. This study is carried out in partial cooperation with the Guelph office of Water Survey of Canada and the N.B. Subcommittee on River Ice. (Beltaos)

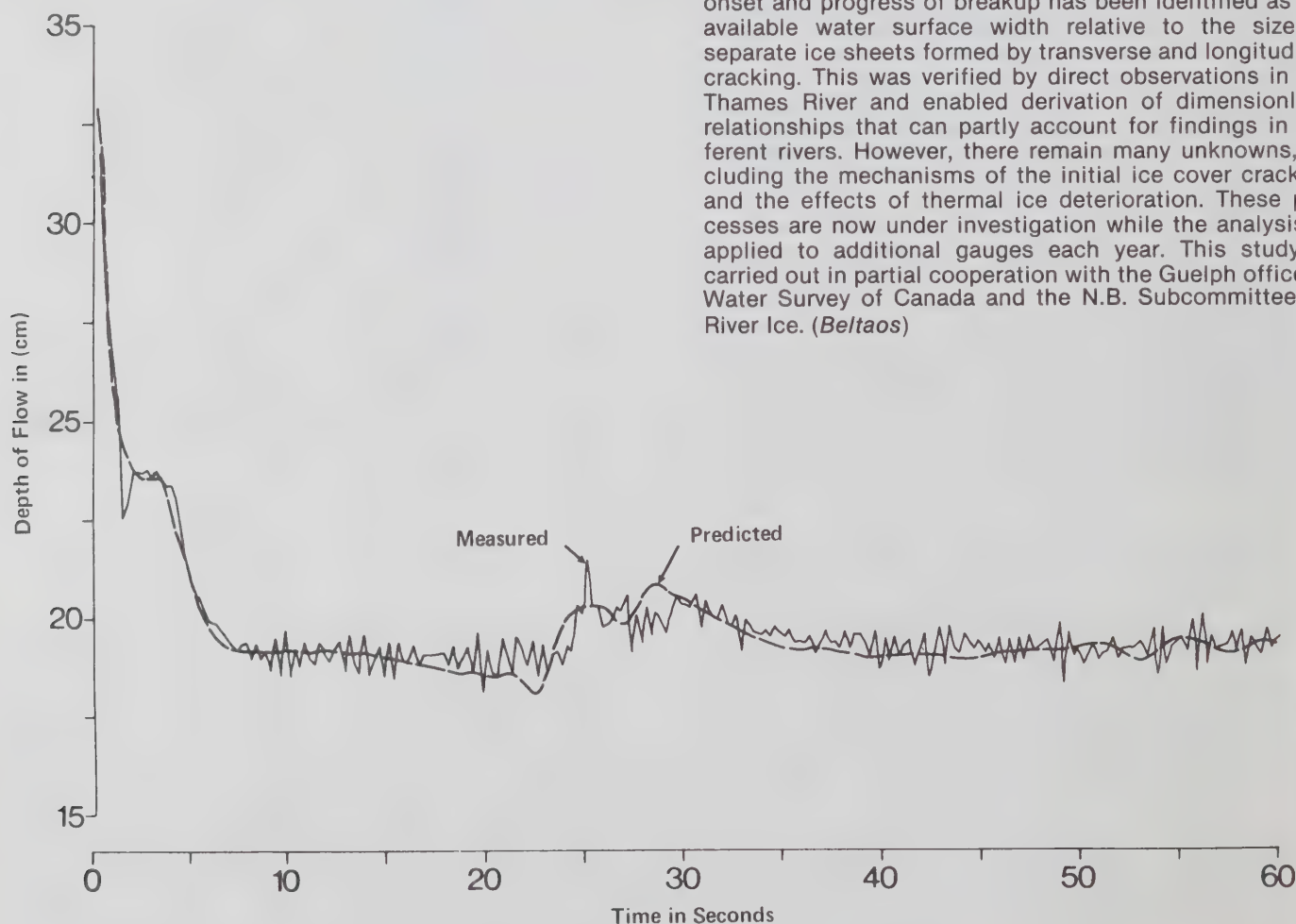


Figure 2. Measured and predicted depth-time variations after ice jam release in a laboratory channel.

The National Research Council of Canada has recently initiated a Working Group on River Ice Jams. The Environmental Hydraulics Section has been invited to chair this Group. Work is in progress on four tasks, i.e., guidelines for needed field data collection programs, guidelines for extracting ice-breakup data from hydrometric station records, identification of research needs, and compilation of case studies. Preparation of a monograph on ice jams is contemplated as a future task. (Beltaos)

**Frazil Ice.** After many years of work, a frazil measurement instrument was successfully developed and tested in the

laboratory to be satisfactory. The instrument has also been adapted to saltwater frazil measurement. In the winter of 1983/84, the instrument was also field tested in the Beauharnois Canal and the experimental results are being analyzed. Further river testing of the instrument and the testing of the instrument in the Arctic under the saltwater environment are being planned for the winter of 1984. The instrument can measure the point concentration of frazil in water to 0.1 percent. Figure 3 shows the prototype of the instrument and a sample of a frazil recording. (Tsang)

A PILP grant has been given to Arctec Canada to market the instrument under licensing. A half a million dollar sales of the instrument in five years has been projected by

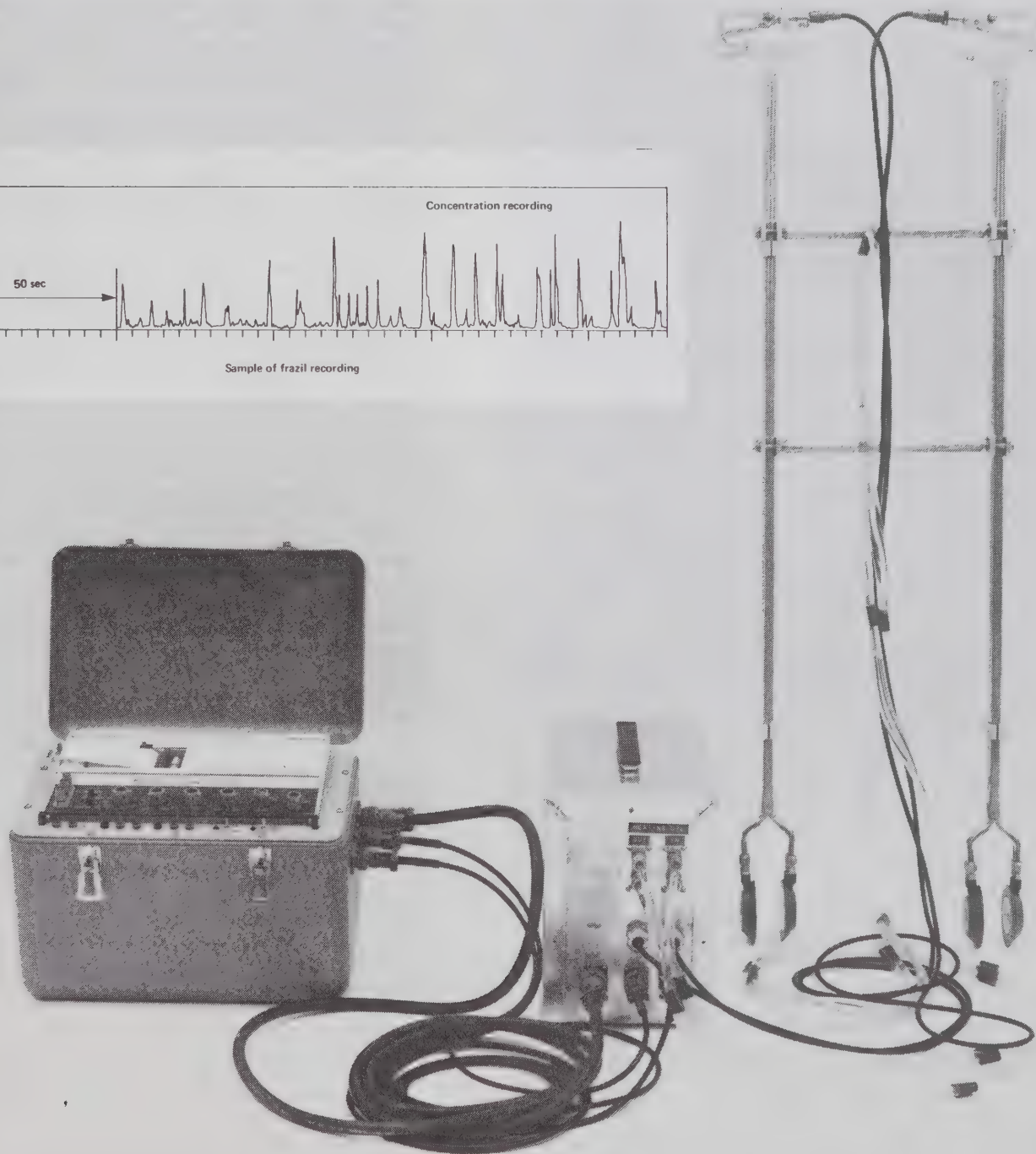
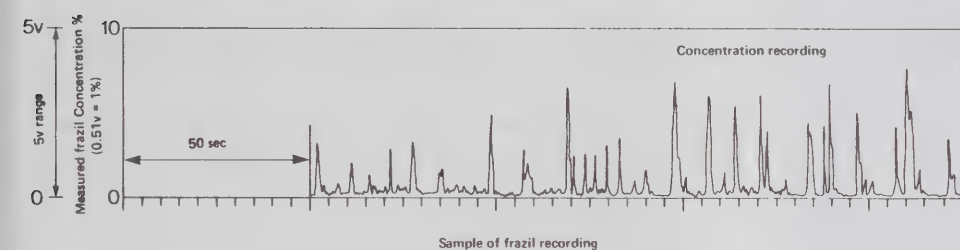


Figure 3. Frazil Instrument



Arctec Canada.

Besides instrumentation development, the formation of frazil in water of different salinities and at different super-coolings was also studied. The property of frazil in fresh water and seawater was found to differ greatly. A small contamination of the freshwater by small amount of salt can greatly alter the physical properties of the ice. A universal semi-empirical equation has been obtained by which the concentration of frazil in frazil producing water under different parametric conditions can be predicted. The crystallography of frazil formed in water of different salinities was and is still being studied. Results may be highly significant for offshore operations in cold regions. (Tsang)

**Modelling of Urban Runoff.** Several studies have been undertaken to develop or refine methodologies for the modelling of urban runoff. Such work focussed on rainfall inputs, pollutant sources, and runoff transport processes. Starting with rainfall inputs, an annotated bibliography on design storms was prepared. Further investigations dealt with temporal distributions for design storms, and finally, a new type of comprehensive urban design storms was proposed and recommended for Canadian practice. In an adjunct study, the feasibility of deriving runoff peak frequency curves from a series of discrete event simulations was demonstrated and the results further served for verification of the Storm Water Management Model. For the applications of this model, a new procedure for catchment discretization into subcatchments was developed. (Marsalek)

Urban runoff quality was studied in Burlington, Ontario and St. John's, Newfoundland. Results of these studies served for identification of sources of pollution in runoff and for establishment of pollutant loading rates which may be transferred to other areas.

In modelling of runoff transport, the division between the surface and subsurface transport routes is an important issue. Such phenomena were studied experimentally for common drainage structures which are used in road and bridge deck drainage. Using the observed data, a new drainage design procedure was developed for the study sponsors, the Ministry of Transportation and Communications. MTC evaluations of this new procedure indicate that it can reduce road drainage costs by about \$50 000 per mile of a fourlane highway.

Runoff transport is also influenced by headlosses at sewer pipe junctions. Such losses then reduce the overall system capacity. Investigations of head losses and means of their reduction were conducted for straight-flow-through junctions, for a 90° bend and for laterals entering at different angles. Recent experimental data for the 90° bend junction indicate a significant loss reduction resulting from the installation of a benching at the junction. These studies are conducted in cooperation with the American Public Works Association. (Marsalek, Ng)

The complexity and large scope of urban water resources studies dictate the necessity to combine the resources and expertise of various agencies interested in such studies. Towards this end, the Hydraulics Division actively participated in the Rideau River Stormwater Management Study, the Toronto Area Watershed Management Study, and the Waterford River Basin Urban Hydrology Study. All these studies addressed the water resources problems caused by progressing urbanization and developed the means of reducing or estimating such adverse effects. (Marsalek)

Another important activity was technology transfer on the national as well as international level. This included

contributions of several chapters to the UNESCO and American Society of Civil Engineers manuals on urban drainage, preparation of a chapter on urban design floods for the Design Flood Guide for Canada, a report on storm-water detention in various countries, and reports on urban hydrology research and urban runoff control in Canada. (Marsalek)

**Persistent Toxic Substances in Urban Runoff.** Urban land runoff has been identified by IJC as one of the major sources of toxics in the Great Lakes Basin. In response to environmental concerns, a field study of PTS in the Niagara River Basin was conducted. Among the 51 substances studied, the highest loadings were observed for heavy metals, followed by polyaromatic hydrocarbons, chlorinated benzenes, PCB's, and organochlorine pesticides. Similar estimates of toxics loadings are now being prepared for the entire Great Lakes Basin. (Marsalek)

## SHORE PROCESSES SECTION

The work of the Shore Processes Section is concentrated in the areas of wind-generated waves and shore evolution.

**Wind-Generated Waves.** A theory was developed for the transfer of gases across natural air-water interfaces. Special effects of surface wave distortion to the air flow and of breaking waves are considered. The theory has been successfully tested against published experimental data and is a considerable step forward in estimating gas transfer to and from lakes and oceans. Results may be very useful for thermodynamic models of long term climate change.

A comprehensive description of the directional properties of wind-generated waves has been gleaned from array measurements in Lake Ontario and the laboratory. The results are significant for improvements in describing wave properties, particularly spectral shapes, spreading functions and propagation speeds.

The sampling variability of spectra of wind-generated waves has been tested against the predictions of the theory of waves as a stationary random quasi-Gaussian process. The theory is found to be applicable and theory and observation indicate that common practice in wave monitoring yields uncertainties of about 12% and 5% in the significant height and peak frequency. (Donelan)

**Wave Direction Buoy.** The performance of the CCIW wave direction buoy relative to other wave direction buoys at the Atlantic Remote Sensing Land Ocean Experiment off Duck, North Carolina is the subject of a paper in a special issue of the IEEE Journal of Oceanic Engineering. Comparison of wave measurements with a nearby Waverider and cloverleaf buoy showed agreement within the sampling variability of both systems. Wind speed measurement show no bias between the CCIW and the XERB buoys, and the scatter appears within the expected mesoscale variability over a separation of 24 km. Some systematic differences were noted in the wind direction measurements between the CCIW and the XERB buoys. Comparisons of nondimensional height and period with independently derived fetch-limited relations yield agreement within the 90% confidence limits of the CCIW buoy. Without an absolute standard, the accuracy of the system cannot be established. However, these comparisons show that CCIW Wave Direction buoy performed well and that the variability of the measurements is about that expected from sampling theory. (Skafel, Donelan)



The wave direction buoy was deployed off Pointe Sapin, New Brunswick in 1983 in support of the Canadian Coastal Sediment Study sponsored by the National Research Council Associate Committee for Research Shoreline Erosion and Sedimentation. (*Skafel*)

**Nearshore Sediment Transport.** A paper describing several years work measuring longshore suspended sediment transport caused by waves at Van Wagner's Beach, Lake Ontario, was presented at the 18th International Conference on Coastal Engineering. The data were collected under some of the largest waves encountered during experiments of this type, although the angle of approach was small. The range of suspended sediment concentrations and the range of transport rates are similar to those reported elsewhere. The relation between longshore transport and longshore energy flux derived from our data suggests that about half the amount of sediment is moved in suspension compared to the total transport reported by Komar and Inman (J. Geophy. Res., 75:30 pp. 5914-4927). (*Coakley, Skafel*)

**Suspended Sediment Distribution in a Wave Field.** Sediment resuspension due to wave agitation has been formulated using the diffusional approach. The classical Schmidt equation is solved to obtain the vertical distribution for time-average sediment concentration. The diffusion coefficient is assumed to be proportional to the product of shear velocity at the bed and orbital velocity just outside of the boundary layer. A bed layer concept is proposed to evaluate the absolute values of sediment concentration as a function of the height from the bed knowing the wave parameters such as the wave height, period and the mean water depth and the sediment characteristics such as the grain size and the specific gravity. Laboratory experiments are used to evaluate the dimensionless diffusion coefficient and the bed layer thickness in terms of the dimensionless parameters controlling the phenomenon. The present formulation is compared with the experimental data of other investigators and a reasonable agreement between the two is obtained. Undertaking of these processes provides essential steps for general modelling of the resuspension and transportation of lake sediments. (*Skafel, Krishnappan*)

**Coastal Processes in Lake Erie.** A comprehensive study was made into the postglacial development of the Lake Erie shoreline, with special emphasis on the origin and evolution of the major forelands which occur there: Long Point and Pointe-aux-Pins. A large amount of relevant geological and geomorphological data was assembled but the main focus was on recently-obtained borehole samples. The sediment profiles constructed represent an excellent record of changes in the critical nearshore depositional environment since the low-level stage following deglaciation. One major conclusion is that lake levels in the Erie basin did not rise uniformly from the initial low-level stage to its present situation. Rather, the lake level trend shows peaks and troughs superimposed on the rising trend. These deviations were apparently associated with major changes in the hydrological regime, while the underlying trend is believed to reflect isostatic and tectonic uplift since deglaciation.

Major forelands formed much further offshore when lake levels were much lower and were originally situated along the crest of existing glacial moraines formed in the lake. With rising lake levels, they migrated northward and gradually assumed their modern form. The evolution of the Long Point foreland is schematically presented in Figure 4. (*Coakley*)

**Erosion Resistance of Cohesive Sediments.** The scour resistance of cohesive sediments is still poorly understood, yet it is of importance in research concerned with shore and subaqueous erosion. The design of a more accurate rotating-cylinder apparatus was completed during the fiscal year 1982-1983. Using the apparatus, it is possible to measure directly and accurately the critical shear stress at which a sediment begins to erode, and erosion rates per unit time and area at higher shear stresses. A testing program is in progress to determine the erosion resistance of two different tills from the Lake Erie north shore. Results of erodibility tests are being related to sediment geotechnical properties, including water content, shear strength, Atterberg limits, and particle size distribution. A bibliography and annotated abstracts of twenty-nine research papers and eleven review papers concerned with erosion of cohesive sediments were compiled in an internal report to provide a perspective for future studies. (*Zeman*)

A model to obtain a relationship between wave energy reaching a cohesive bluff and the rate of erosion was tested using available data. A linear relationship between recession and wave energy normal to the bluff was found. The geotechnical processes contributing to the erosion of the bluff were shown to be significant but the influence of the nearshore sand layer was not established. (*Dick, Zeman*)

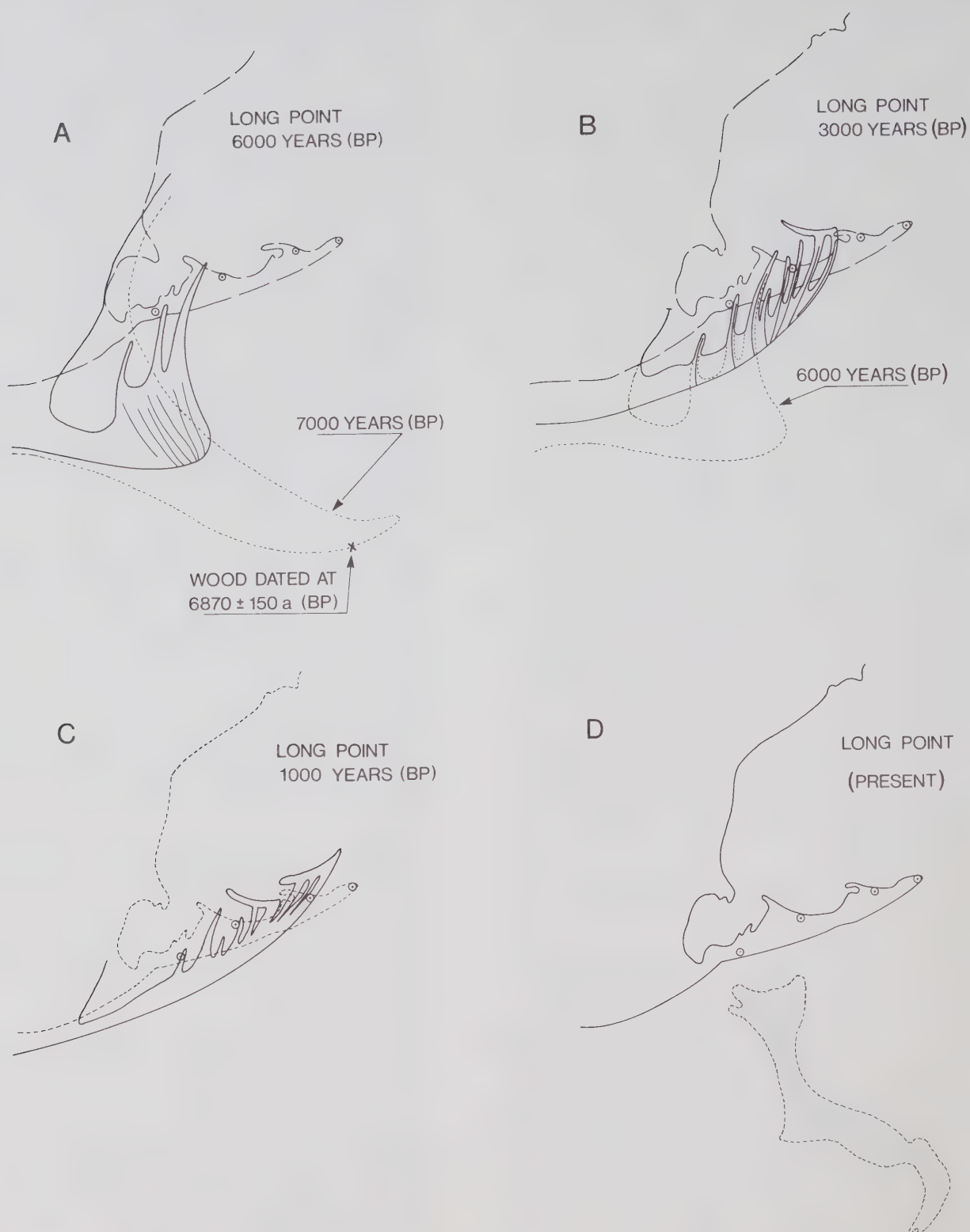
**Geotechnical Study of Eroding Bluffs.** Monitoring of pore pressures at the study site, which is located approximately 3 km east of Port Burwell on the Lake Erie north shore, was terminated in June 1983 when a massive landslide destroyed cables leading to two remaining piezometers. A continuous record of pore-pressure data for a period immediately preceding the landslide has been retrieved. Two survey lines were measured in the summer of 1983 to establish bluff-slope profiles at the end of the monitoring program. During the eight year period of monitoring, the bluff receded by about 36 metres at the two sites where piezometers and slope-indicator casings were installed. (*Zeman*)

**Eleventh International Congress on Sedimentology, Hamilton, Ontario, August 1982.** J.P. Coakley and A.J. Zeman participated in the organization of IAS Field Trip 9B. They acted as guides for the first day of the trip, which focussed on shoreline forms representative of the Lake Erie north shore, high, rapidly retreating bluffs in the Port Burwell area, and the sandy beaches and dunes of the Long Point Foreland.

**Nearshore Sediment Program.** All nearshore sediment data for Lakes Ontario, Erie, Huron and Georgian Bay have been edited and archived as a series of computer files. Data on surface-sediment samples and cores, sediment-thickness and nearshore bathymetry have been subdivided into records on the basis of location; each record corresponds to one of the National Topographic Series 1:50 000 maps. The records and a procedure designed to retrieve them have been transferred to the Data Management Section along with responsibility for handling routine requests for nearshore data.

A cooperative study funded by the Ontario Geological Survey was set up with the University of Guelph to report on the nearshore deposits of eastern Lake Ontario and on the resource potential of Lake Ontario nearshore deposits in general. Further work in this area included the preparation of two reports for OMNR on the nearshore sand and gravel deposits of Lakes Ontario and Erie. (*Rukavina*)





**Figure 4.** Schematic Reconstruction of the Evolution of Long Point, based on the Lake Level History Changes in the Pattern and Orientation of Beach Ridges Preserved on the Point and Borehole Sediment Interpretations.

**Third Coastal Workshop.** The Hydraulics Division hosted the Third Workshop on Great Lakes Coastal Erosion and Sedimentation at CCIW on November 1-2, 1982. Forty-five invited attendees participated in a program of research summaries and discussions of coastal engineering practice and research needs. A proceedings volume has been published and is available from the National Research Council, Ottawa. (*Rukavina*, Editor)

**Floating Tire Breakwater Research.** A field program to monitor the Goodyear floating tire breakwater in Burlington, Ontario, was successfully completed. Wave transmission and mooring force data were collected using a Sea-Data logger, two submerged pressure cells, and three electronic and four mechanical load cells on a 128 m long by 18 m wide test section. Good data was obtained during three storms (September to November, 1982). Results from these field measurements will be compared with existing design information from model tests.

Random-wave tests of Pipe-Tire and Goodyear floating tire breakwaters made from 8.5 cm diameter tires were conducted.

The buoyancy requirements of three types of floating tire breakwaters (Wave-Maze, Goodyear, Pipe-Tire) were

determined in a desk study, with some supporting laboratory measurements of prototype tires. Flotation balance equations were derived to allow the estimation of supplemental flotation requirements for a given floating tire breakwater under any known site specific conditions. A report was completed.

A cooperative effort with the New York State Sea Grant Extension Program and the University of Rhode Island Marine Advisory Service has produced a guideline report on floating tire breakwaters. (*Bishop*)

**Shore Protection.** A review of existing literature on shore protection was conducted. Shore erosion is recognized as a predominantly natural process that can be mitigated or aggravated by the actions of man. In cases where shore protection is warranted, a possible alternative to the use of seawalls, groynes or artificial beach nourishment is the use of artificial headlands. The equilibrium plan geometry of headland-bays has a characteristic log spiral shape that is predictable if there is a known dominant wave energy direction (Fig. 5). Empirical design information is provided in two reports. (*Bishop*)

**Port Burwell Comparative Literature Study.** Literature was

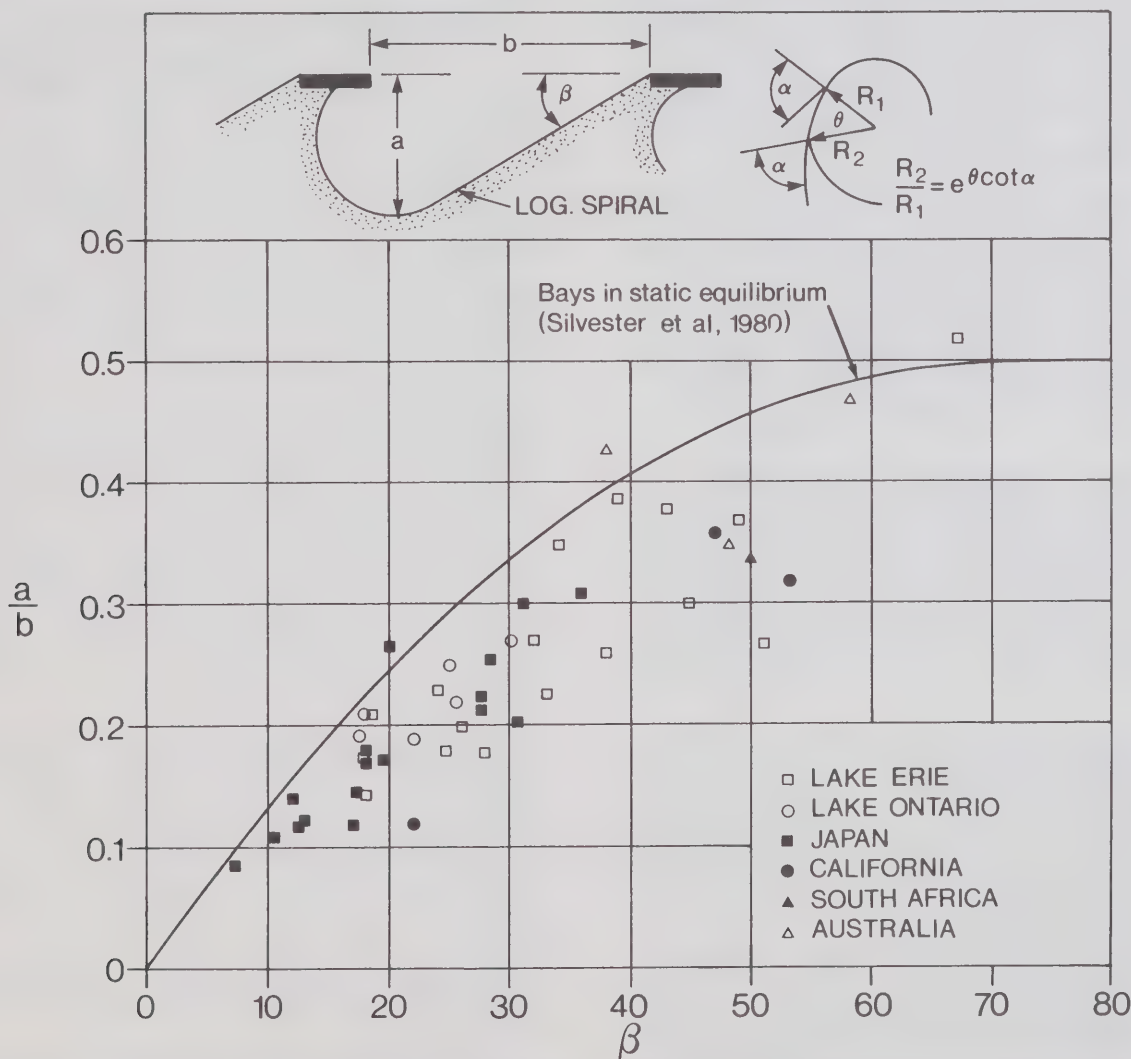


Figure 5. Measured values of the ratio of bay indentation to headland spacing versus the obliquity of the dominant waves to the headland alignment for some natural headland bays.

reviewed, summarized and critically evaluated relating to two topics associated with the erosion of till bluffs near Port Burwell on Lake Erie. One report dealt with site specific studies of harbour structures thought to have impacted on shore erosion. The other dealt with studies of the behaviour of cohesive coasts. (Bishop)

**Harbour Models.** Two hydraulic models were constructed and tested in the Hydraulics Laboratory. The harbour at Glace Bay, Nova Scotia, was modelled at a scale of 1:60 to investigate remedial works to improve wave conditions within the existing harbour. The entrance to a proposed small craft marina at Lakefront Promenade Park, Mississauga, Ontario, was modelled at a scale of 1:36 to determine several feasible entrance breakwater configurations. Both studies were conducted in support of Small Craft Harbours, Fisheries and Oceans Canada. (Bishop)

## TECHNICAL SERVICES SECTION

The Section provides technical support to scientists and engineers conducting research in the Hydraulics Laboratory and related field work.

An important function of the Section is the operation of the National Calibration Service which undertakes calibration and performance evaluation tests on all current meters and sediment samplers for Water Survey of Canada with its vast network of over 3000 stations across Canada. Different types of hydrometric equipment and current meters are also calibrated for other federal agencies, provinces, municipalities, consulting engineering firms and others in the private sector.

**Shore Processes Support Unit.** Technical staff of the unit are assigned to research studies under guidance of the scientists of the Shore Processes Section. The unit operates sedimentological and geotechnical laboratories where grain size and geotechnical analysis of sediment samples and cores are undertaken. These facilities provide support for ongoing research within the Division as well as a service to other government agencies, universities and the private sector.

**Environmental Hydraulics Support Unit.** Assistance was provided to scientists and engineers conducting research in the Hydraulics Laboratory and related field work. This period has seen an increase of activities for the staff as support was also provided for third parties under the Department's cost recovery policy. Several harbour models were constructed in the wave basins and tests were conducted in the wind wave flume, towing tank and environmental flumes.

**Laboratory Operations Unit.** Support to users of the Hydraulics Laboratory was provided in areas such as carpentry, machining and equipment maintenance. The supervision of outside contractors working in the laboratory, advice and consultations with scientists and engineers on problems and the inventory and procurement of materials and supplies were also undertaken.

**National Calibration Service.** The National Calibration Service was re-organized into a unit of four members. The responsibility of electronic design, maintenance and advice has become part of this service mandate. The first phase of the replacement of the towing carriage data acquisition system has been completed involving the procurement, installation and testing of the microcomputer system. Software development by Data Management is

continuing. A total of 161 requests were processed resulting in 984 calibrations and 641 hours of testing.

**Effects of Transverse Velocity Gradients on the Performance of the Price Current Meter.** Theoretical analysis and experimental data were used to show that the Price meter registers incorrectly when the approaching flow has a transverse velocity gradient. The error can be several percent. (Engel)

**Comparison of Current Meter Calibrations from Different Towing Tanks.** Owing to the initiative of Québec-Hydro engineers, comparative ratings of five Siap ME 4001 type current meters were made at four different towing tank facilities. These facilities were located at: Institute Di Idraulica, University of Perugia, Italy; Station d'Étalonnage de Moulinets Hydrométriques de Beauvert, Grenoble, France; Eidgenössisches Amt für Wasserwirtschaft, Berne, Switzerland; and the National Water Research Institute, Burlington, Canada. Analysis of the data has shown that this type of meter can be calibrated to an accuracy of 0.4% at the 99% confidence level. The study further demonstrated that the calibration accuracy in the towing tank at Burlington equals or exceeds that obtained at the other towing tank facilities. (Engel, DeZeeuw)

## ENGINEERING SERVICES SECTION AND MANUFACTURING AND TECHNICAL DEVELOPMENT SECTION

The activities undertaken by the two engineering support sections involve all phases in the equipment life cycle, from conception and definition, through detail design, manufacture, and commissioning, to maintenance and modification as required.

In the reporting period, some 60 separate projects were undertaken, of which 13 were new systems, 26 were new items of equipment, and 21 were maintenance or modification to existing equipment.

**River Ice.** Two frazil ice measurement systems were carried to laboratory prototype stage. One is based on the conductivity principle suggested by Tsang (1983). This is a portable sensor, suitable for spot measurements through holes in the ice surface (Fig. 3). A second system is based on the principle of a through-flow calorimeter. The sensing head of this system is designed for season-long installation in the stream. A shore station with recording facilities provides long term time series measurements of frazil concentrations, as well as alarm signal outputs to warn of excessive ice concentrations or system functional problems. (Ford for Burrell, WRB, MOE, N.B.)

The condition of the under surface of the ice cover influences river flows thus the ability to see hanging dams of frazil ice and to examine the under surface of jams is useful. The under-ice video system (Fig. 6) was designed and constructed to obtain video presentation and recording from a camera which may be inserted through a small hole in the ice. The portable, weather-tight equipment has been used by Water Survey of Canada in New Brunswick for river ice study. It has also been found useful by Fisheries and Oceans biologists in the Arctic for viewing biota under sea ice. (Valdmanis for Burrell, WRB, MOE, N.B.)

Ice thickness profiles are required for operational and research programs. After a review of various approaches (Watson, 1982), a decision to apply existing ground probing radar technology for ice thickness has been made. Con-



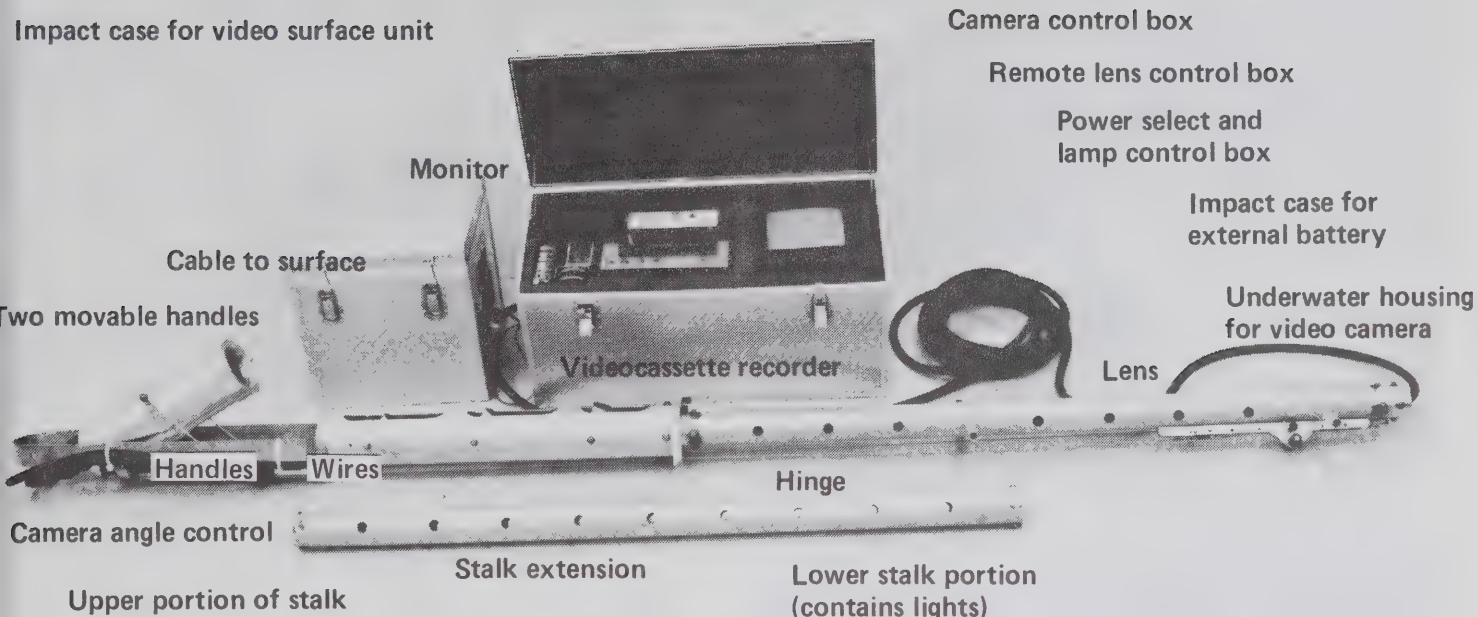


Figure 6. Under Ice Video System

tracts have been undertaken with outside consultants to establish the performance requirements of such radar. (Watson for Burrell, WRB, MOE, N.B.)

**Bottom Shear and Sediment Transport Instrumentation.** The character of the bottom boundary layer in lakes is essential information for modelling of lake circulation and of sediment transport.

For the 1982 summer period, the Benthic Boundary Array System was produced to obtain time series episodes of water current, and temperature at three elevations in the 0.5 m thick bottom layer. The system has a capacity to record 10 minute sequences every three hours for 23 days. Two field deployments demonstrated a 99.9% data return during the Lake Ontario Coastal Study at Cobourg. During the 1983 season, a simpler, lower cost sensor platform designated CATS/83, was designed, built, and tested. This system carries one electro-magnetic current meter 1 m from the bottom, four thermistors arranged to profile the bottom temperature gradient, a pressure transducer, an attitude indicator, and a data logger. This system collects data to supplement that obtained with BBA. (Desrosiers for Boyce, APSD)

A sediment resuspension sampler was designed and built to determine sedimentation rates and estimate resuspension in the bottom 10 m layer. This device comprises a set of tube traps supported at intervals from the bottom. All the traps are sealed during deployment, and the caps automatically removed 60 minutes after deployment by operation of an electronic timer controlling a pneumatic system. (Savile for Rosa, AED)

**Lake Dynamics Instrumentation.** Development of the Generalized Automatic Profiling System (GVAPS) has been underway for several years. In 1982, the system was deployed as part of the Lake Ontario Coastal Study. The GVAPS collects long time series of synoptic profiles of water velocity and temperature versus depth at a fixed location. The profiled data has a depth resolution of 10 cm

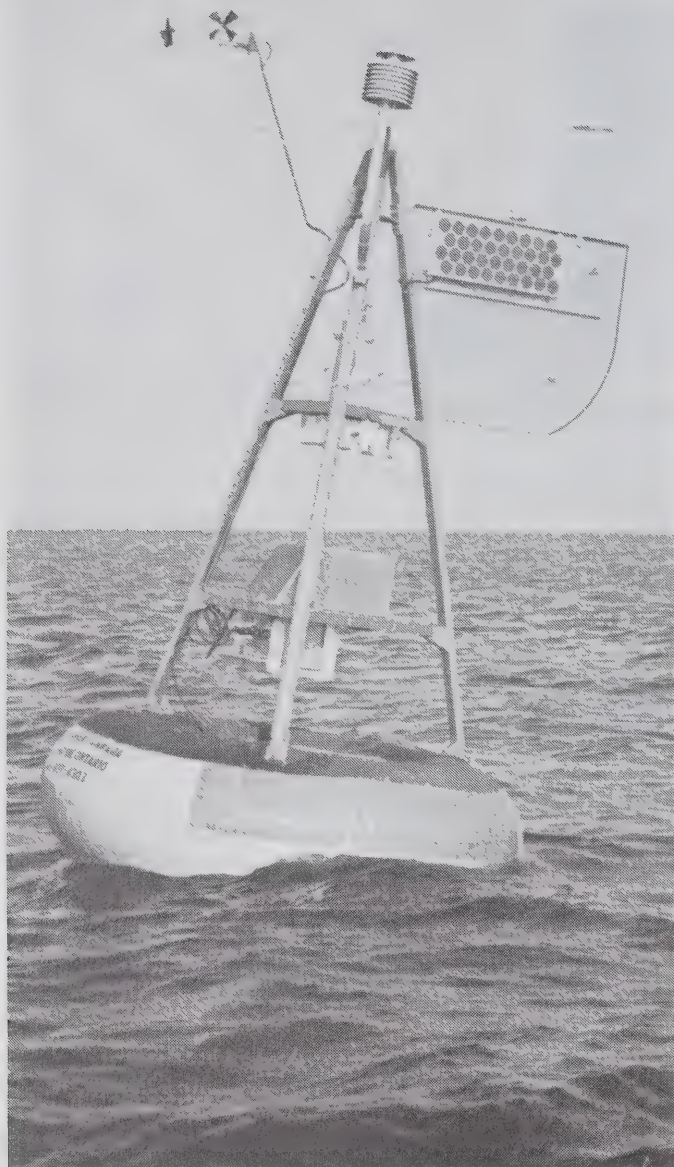
and a time resolution of about 30 minutes. (Roy for Boyce, APSD)

Measurement of meteorological conditions at the lake surface is essential to supplement other air and water mass observations. The development and field testing of a second generation meteorological data buoy (MET II) to replace existing equipment was conducted in 1982 and 1983. The MET II will provide an instrument complement of improved accuracy and reliability. Solar power and satellite monitoring systems as well as increased recording capacity have been added to extend the time between visits by field crews. It is expected that the MET II will be phased into the operational inventory in 1984 (Fig. 7). (Valdmanis for Boyce, APSD)

Studies of current meters were also conducted during the 1982/83 period. In some cases of oscillating flow, distortions in the flow past spherical sensing head type meters can cause a bias in averaged readings. An analytical and experimental study was carried out to evaluate the significance of this distortion in the range of Reynolds Number typical of shallow lake and nearshore application. (Ford)

In 1983, preparatory to a major program for replacement of obsolete current meter inventory, an intercomparison study of current meters from six manufacturers was conducted. This involved field deployment in Lake Ontario for a four week period, followed by post field calibration tests in the Hydraulics Division tow tank. As part of this task, and also in support of a Fisheries and Oceans current meter calibration study, a universal current meter mount was designed and built for use with the Hydraulics Division tow tank carriage. This mount allows the meter to be held rigidly under test at 15° increments over 360° rotation in azimuth and 5° increments over 30° of inclination angle over the full range of carriage speed. The experience and data obtained from azimuthal and inclined axis will provide a basis for selection of meters required for the next several years. (Baird, Valdmanis)





**Figure 7. MET II Buoy**

Equipment for the laboratory study of lake dynamics was also produced. A hydraulically driven wave machine was designed and built for the Cold Room Flume in the Hydraulics Laboratory. An accessory to this was a remotely controlled profiler to carry hot wire anemometers for profiling the air stream above the flume surface. (Valdmanis, Donelan)

**NWRI Sea/Air Direction-Sensing Buoy (P.I.L.P. Program).** This NWRI buoy system, together with its data-processing software, was put forward as a candidate for possible technology-transfer to the private sector, with a view to ultimate commercialisation. This submission was approved by the NRC/Interdepartmental PILP Review Board. A contract for Phase One — analysis of the potential market which this technology might stimulate — is underway with Lapp Associates, Toronto. (Watson for Donelan)

**Harbours and Breakwater.** Modifications were made to the Kelk wave machine to extend the range of paddle motion

from purely hinged motion to a combination of hinged and piston motions. (Madsen, for Skafel)

A special sensor and data logging system was provided to measure the effectiveness of a floating tire breakwater installed for the La Salle Marina, Hamilton Bay. Sensors included wave pressure, mooring forces, wind speed and wind direction. Threshold sources were used to limit recording observations to significant events. (Valdmanis, for Bishop)

**Water Quality Instrumentation.** Systems and equipment to support water quality studies were provided.

The Shipboard Radiometer System measures the spectral volume-reflectance of lake water. In 1983, a digital data logger was included, and the system was installed on CSS LIMNOS during the Lake Superior Study cruises. (Watson for Bukata, APSD)

An oxygen profiling sensor system comprising a sonde, computer controlled winch, and a North Star desk top computer was produced for Aquatic Ecology Division. This system allows semi-automated operation of the winch and sonde to profile and log dissolved oxygen, temperature, and depth with much greater facility than previous techniques based on water sampling and Winkler titration methods. Field tests of the system were conducted in 1983, as well as a series of survey cruises on Lake Erie. (Ford for Charlton, AED)

Two pieces of equipment for field preconcentration of organic contaminants in water samples have been developed. The portable centrifuge, used to separate contaminant bearing particulates from through-flow sample water, is based on the standard centrifuge used by NWRI. Modifications have been made to reduce its mass, provide portability, and replace the electric motor drive with a gasoline engine. The Aqueous Phase Liquid Extractor (APLE) has been miniaturized to provide a highly transportable unit for field use. This unit thoroughly mixes the water sample with a dense organic solvent which preferentially dissolves organic materials in the water. After mixing, the solvent settles to the bottom of the drum, where it can be drawn off, giving an initial concentration increase of 19 to 1 over that of the original water sample. Further evaporation of the solvent increases the contaminant concentration, allowing identification and measurement. (Savile for McCrae, WQB.)

A water surface micro-layer sampler was designed and built for Environmental Contaminants Division, based on Harvey (1966). This device is essentially a porcelain coated cylinder, rigged with its axis horizontal, and supported on a pair of pontoons. The cylinder is driven by a variable speed electric motor. The apparatus is designed for attachment to a 16 foot Boston Whaler. The sample is collected by means of the surface tension between the water and the drum, the speed of which is adjusted to match the translation speed over the water surface. Field evaluations in 1983 were qualitatively successful. Quantitative calibration tests are planned for 1984 prior to extensive field application (Platford et al, 1983). (Madsen for Platford, ECD)

Since 1975, IWD/Water Quality Branch has been conducting a daily sampling program at Niagara-on-the-Lake based on an automatic sampler designed and built by the Engineering Support Sections. This sampler, controlled by a series of timers, is designed to collect and store samples on either a daily or hourly schedule depending on program objectives. The station at Niagara-on-the-Lake monitors inflow into Lake Ontario. A second station at Wolfe Island near Kingston monitors lake outflow into the St. Lawrence. The success of this methodology led in 1983 to the con-

struction and installation of a third station at Fort Erie Ontario, at the outflow from Lake Erie. This newest sampler retains the basic design features of the earlier two, and incorporates some modifications to details arising from the extended operational experience. (*Boucher* for McCrae, WQB)

**Calibration Laboratory.** The Calibration Laboratory provides the transfer standards for calibration of sensors on all measurement systems used by the Institute.

During 1983, the Calibration Laboratory entered a joint program with Tidal Development and Engineering Support, Canadian Hydrographic Service, to develop a mobile absolute pressure calibration station to meet the high standards of depth transducers now in use in recording tide gauges and other systems. The new station upgrades obtainable accuracy from 0.025% to 0.01%, enables absolute pressure calibrations to be made, and may be easily moved to other test stations to allow two variable calibrations, e.g., temperature and pressure simultaneously. (*Mollon* for White, BLMSS)

### DRAFTING SERVICES SECTION

The Drafting Services Section provides a Centre-wide service by undertaking graphic, technical and scientific illustrations as well as cartographic, mechanical and electronic drawings of a quality suitable for publication purposes. The Section also provides a photographic service which includes photography of engineering and scientific research equipment, overhead projection materials and slides for conferences and seminars and provides, through outside sources, the requirements for reprographic and photofinishing services.

In preparation for Open House '82, the drafting office processed over 3000 items which included drawings, photographs, text and headings for displays. Photographic coverage included opening ceremonies, panel discussion, general public relations and a complete record of individual displays.

The Drafting Service also provided the facilities for and coordinated a project for the Canada NEED Program which entailed the updating and metric conversion to the architect's original drawings of the Canada Centre for Inland Waters building plans by a team of architectural drafting personnel.

### OFFICE SERVICES SECTION

This Section provides office services, word processing, clerical and record-keeping support to all Sections of the Divisional operations. Office Services manages the orderly production and distribution of reports and publications on scientific and engineering subjects, implementing the bilingual publishing policy of the Department of the Environment, and ensuring the communication of new information and knowledge to all sectors of society in Canada. The Section maintains a permanent file of all research and technical reports, and responds to requests for reprints or copies of unpublished manuscripts.

Statistics on requests for publications have been maintained since 1976. The relevance of the work to the scientific community is indicated by the continual increase of the number of requests for reports and publications. In the calendar years 1982 and 1983, approximately 1700 reports have been distributed.

### STAFF LIST

**Chief — Dr. T.M. Dick**  
**Secretary — Mrs. A. Mueller**  
**Administration Officer — Mrs. C. Leacock**  
 (assigned to Hydraulics Division by  
 Staff Services Division, NWRI)

**Drafting Services Section**  
 Head, Mr. W.D. Finn

**Draftspersons**  
 Mr. M. Donnelly  
 Mrs. J. Field  
 Mr. P. McColl  
 Mr. J. Van Nynatten

**Engineering Services Section**  
 Head, Mr. F.E. Roy

**Project Engineers**  
 Mr. R. Desrosiers  
 Mr. J.S. Ford, P.Eng.  
 Mr. E. Harrison, P. Eng.  
 Mr. N. Madsen  
 Mr. A.E. Pashley, P. Eng. (retired April 1983)  
 Mr. J. Valdmanis, P. Eng.  
 Mr. A.S. Watson, P. Eng.

**Environmental Hydraulics Section**  
 Head, Dr. Y.L. Lau                      river dynamics

<b>Researchers</b>	
Dr. S. Beltaos	river ice studies
Mr. P. Engel	river engineering
Mr. B. Greck	urban hydrology
Dr. B.G. Krishnappan	river dynamics
Mr. J. Marsalek	urban hydrology
Mr. H. Ng	urban hydrology
Dr. G. Tsang	ice studies
Mr. J. Wong	river ice studies

**Manufacturing and Technical Development Section**  
 Head, Mr. S.D. Baird

**Electronic Development**  
 Mr. J. Dolanjski  
 Mr. M. Pedrosa

**Mechanical Development**  
 Mr. R. Boucher  
 Mr. P. Carney  
 (presently with National Defence Headquarters, Ottawa)  
 Mr. H. Savile

**Instrument Calibration Laboratory**  
 Supervisor, Mr. K. Mollon  
 Mr. L. Peer  
 Mr. J. Thompson

**Machine Shop**  
 Supervisor, Mr. D. Whyte  
 Mr. J.G. Ford (joined Division November 1982)  
 Mr. K.K. Kalter  
 Mr. G. Olsen



#### Office Services Section

Head, Mrs. M. Hawkins

Mrs. D. Bowman, Divisional Clerk  
Mrs. E.J. Jones, Word Processing Operator  
Mrs. N. Snelling, Word Processing Operator

#### Shore Processes Section

Head, Dr. M.G. Skafel      coastal engineering

##### Researchers

Mr. C.T. Bishop      coastal engineering  
Mr. J.P. Coakley      coastal sedimentology  
Dr. M.A. Donelan      air-water-interaction  
Dr. N.A. Rukavina      coastal sedimentology  
Mr. A. J. Zeman      geotechnical studies

#### Technical Services Section

Head, Mr. C. DeZeeuw

##### Laboratory Operations Unit

Mr. R. Klainka  
Mr. E. Nash  
Mr. G. Voros, Unit Head

##### Environmental Hydraulics Support Unit

Mr. D. Doede  
Mr. F. Dunnett  
Mr. J. Heidt, Unit Head  
Mr. W. Moody Mr. R. Stephens

Mr. B. Trapp

##### Shore Processes Support Unit

Mr. D. Beesley  
Mr. J. Dalton  
Mr. G.A. Duncan, Unit Head  
Mr. K. Hill  
(presently with Technical Operations Division, NWRI)  
Mr. K. Salisbury

##### National Calibration Service

Mr. C. Bil  
Mr. D. Fekyt, Unit Head  
Miss B. Near  
Mr. T. Nudds

### COMMITTEE MEMBERSHIP

#### S. Beltaos

IAHR Working Group on Thermal Regimes  
IAHR Working Group on Ice Jams  
CSCE Hydrotechnical Committee  
NRCC Subcommittee on Snow and Ice  
NRCC Subcommittee on Hydraulics of Ice-Covered Rivers  
NRCC Working Group on River Ice Jams — Chairman  
New Brunswick Subcommittee on River Ice

#### J.P. Coakley

Program Committee, IAGLR, '84 Conference

#### T.M. Dick

International Association for Hydraulics Research (IAHR) — Council Member 1982/83

International Association for Great Lakes Research (IAGLR) — Board Member and Treasurer

IWD Research Coordination Committee — Chairman

Canadian Society for Civil Engineering — Chairman, Keefer Medel Selection Committee

Editorial Board, WHO "Water Quality Bulletin"

Associate Committee for Research on Shoreline Erosion and Sedimentation (ACROSES) — NRC — Chairman

#### M.A. Donelan

American Meteorological Society's Committee on "Interaction of the Sea and Atmosphere"

"Air-Sea Interface Working Group" of the Radarsat Oceans Team

#### J.S. Ford

Mohawk College Technology Advisory Committee

#### B.G. Krishnappan

Bridge Hydraulics Project Committee of Roads and Transportation Association

CSCE Task Force on Mixing Processes in Rivers

Ph.D. Supervisory Committee, Department of Mechanical Engineering, University of Waterloo

#### Y.L. Lau

Canadian Society for Civil Engineering, Hydrotechnical Division Research Committee

#### J. Marsalek

Working Group on Urban Hydrology (under the International Hydrological Program of UNESCO)

Urban Water Resources Research Council of ASCE

Editorial Board, "Eau du Québec" Journal

Stormwater Management Task Force of CSCE

Technical Committee for the Waterfront River Basin Study

Ph.D. Supervisory Committee, Department of Civil Engineering, McMaster University

#### N.A. Rukavina

Ph.D. Supervisory Committee, Department of Geography, McMaster University

#### J. Valdmanis

Current Meter Measurement Committee (affiliated with IEEE and MTS)

#### A.J. Zeman

NRC Committee on Marine Geotechnical Engineering

Program Committee, IAGLR '84 Conference

## PUBLICATIONS

- Baird, S.D., T. Nugent, and H. Savile** 1983. An Azimuth Current Meter Test Fixture. NWRI Unpublished Report.
- Baird, S.D., B. Dilkes, and E.O. Lewis** 1983. Azimuth Response Characteristics of the Marsh & McBirney Current Meter. DFO/BLMSS Unpublished Report.
- Beltaos, S.** 1982. River Ice Jams: Theory, Case Studies, and Applications. J. of Hyd. Div., ASCE. (In press).
- Beltaos, S.** 1982. Dispersion in Tumbling Flow. ASCE J. of Hyd. Div., 108: HY4
- Beltaos, S. and B.G. Krishnappan** 1982. Surges from Ice Jam Releases: A Case Study. Can. J. of Civil Eng., 9:2.
- Beltaos, S.** 1983. Ice Jams. Proceedings of ASCE Hydraulics Division Conference on Frontiers in Hydraulic Engineering, held at Cambridge, Mass., Aug. 1983, p. 230-235.
- Beltaos, S., and R. Lane** 1982. Ice Breakup Characteristics of the Nashwaak River at Durham Bridge, N.B. NWRI Unpublished Report.
- Beltaos, S.** 1982. Notes on Ice Hydraulics. NWRI Unpublished Report. Presented at IWD Training Seminar on Hydraulics of Ice Covered Rivers and Ice Jam Analysis, Hull.
- Beltaos, S.** 1983. Ice Freeze Up and Breakup in the Lower Thames River — 1980-81 Observations. NWRI Unpublished Report.
- Beltaos, S.** 1983. Guidelines for Extraction of Ice-Breakup Data from Hydrometric Station Records. Prepared for the NRC Working Group on River Ice Jams.
- Beltaos, S.** 1983. A Conceptual Model of River Ice Breakup. Accepted for publication in CJCE.
- Beltaos, S.** 1983. Research Proposal to Improve Techniques for Breaking Ice Jams. NWRI Unpublished Report.
- Beltaos, S.** 1983. (Discussion) Ice Jams in Shallow Rivers with Flood Plain Flow. Submitted to CJCE.
- Bishop, C.T.** 1982. Floating Tire Breakwater Design Comparison. ASCE Journal of the Waterway, Port, Coastal and Ocean Division, 108:WW3, p. 421-426.
- Bishop, C.T.** 1983. Comparison of Manual Wave Prediction Models. ASCE Journal of Waterway, Port, Coastal and Ocean Engineering, 109:1, p. 1-17..
- Bishop, C.T.** 1983. Research into Floating Tire Breakwaters and the Headland Defence of Coasts. Proceedings Third Workshop on Great Lakes Coastal Erosion and Sedimentation, National Research Council, Ottawa, p. 103-106.
- Bishop, C.T.** 1983. A Shore Protection Alternative: Artificial Headlands. Proceedings Canadian Coastal Conference 1983, National Research Council, Ottawa.
- Bishop, C.T., B. DeYoung, V.W. Harms and N. Ross** 1983. Guidelines for the Effective Use of Floating Tire Breakwaters. Cornell University Information Bulletin No. 197, Ithaca, New York. November, 1983.
- Bishop, C.T.** 1982. Floating Tire Breakwater Buoyancy Requirements. NWRI Unpublished Report.
- Bishop, C.T.** 1982. A Review of Shore Protection by Headland Control. NWRI Unpublished Report.
- Bishop, C.T.** 1983. Port Burwell Comparative Literature Study, Part One, Impact of Harbour Structures. NWRI Unpublished Report. (Restricted Distribution)
- Bishop, C.T.** 1983. Port Burwell Comparative Literature Study, Part Two, Studies of Cohesive Coasts. NWRI Unpublished Report. (Restricted Distribution)
- Bishop, C.T. and D. Lajoie** 1983. Glace Bay Harbour Investigation of Wave Agitation and Related Remedial Structures. NWRI Unpublished Report.
- Bishop, C.T.** 1984. Lakefront Promenade Park Marina Entrance Modelling Study. NWRI Unpublished Report.
- Bishop, C.T.** 1984. Measuring Waves with Pressure Transducers. NWRI Unpublished Report. (In press).
- Bishop, C.T.** 1984. Modelling Wave Agitation in Small Craft Harbours. Paper for presentation at Seminar on Coastal Engineering, Queen's University, Kingston, Ontario.
- Coakley, J.P.** 1982. Borehole Stratigraphy of Lake Erie Postglacial Deposits. Proceedings Third Workshop on Great Lakes Coastal Erosion and Sedimentation, National Research Council, Ottawa, 1983, p. 73-76.
- Coakley, J.P. and M.G. Skafel** 1982. Suspended Sediment Discharge on a Nontidal Coast. Proceedings of the 18th International Conference on Coastal Engineering, Cape Town, S.A. November 1982.
- Coakley, J.P.** 1983. Sub-surface Sediments and Late Quarternary History of Long Point, Lake Erie. NWRI Unpublished Report.
- Dalton, J.** 1983. Nearshore Profile Changes in the Great Lakes. NWRI Unpublished Report.
- Davidson-Arnott, R., B. Greenwood, J.P. Coakley and A.J. Zeman** 1982. Coastal Sediments and Geomorphology of the Canadian Lower Great Lakes. Eleventh International Congress on Sedimentology, Field Excursion Guide Book, Excursion 9B, August 1982, 169 p.
- Desrosiers, R.** 1982. Interim Report on the Calibration of Three Submersible Radiometers for the Research Tower Profiler.
- Desrosiers, R.** 1983. "MCATS" (Moveable Current and Temperature System) Field Trials 1981. NWRI Unpublished Report.
- Desrosiers, R.** 1983. Comparison of Turbidity Sensors with Latex Spheres and Formozia. NWRI Unpublished Report (revised).
- Desrosiers, R.** 1982. NWRI Multiband Transmittance and Temperature Profiler. Operating Manual.
- Desrosiers, R.** Operating Manual for a Transmittance Digitizing System using a Vidicom and a Norpak Image Display and Manipulation System (VIDS).
- Desrosiers, R.** 1983. Transmittance Sensor for 1981 CATTs. Manual (In press).
- Desrosiers, R.** 1983. Benthic Boundary Array Manual. (In press).
- DeZeeuw, C.** 1982. Calibration Procedures for OTT 'V' Arkansas Type Water Current Meters. NWRI Unpublished Report.
- DeZeeuw, C.** 1982. Calibration Procedures for Marsh-McBirney Model 201 Electromagnetic Water Current Meter. NWRI Unpublished Report.
- DeZeeuw, C.** 1982. Calibration Procedures for General Oceanics Type 2030 Water Current Meter. NWRI Unpublished Report.
- Dick, T.M. and A.J. Zeman** 1983. Coastal Processes on Soft Shores. Proceedings Canadian Coastal Conference, NRC, Vancouver, B.C., May 1983, p. 19-35.
- Dick, T.M.** 1982. Priorities in Research, Shores of the Great Lakes. Keynote Address, Proceedings, Third Workshop on Great lakes Coastal Erosion and Sedimentation, NRC, Burlington, Ontario, November 1982, p. 3-6.
- Dolanjski J.** 1982. Handbook Notes for Automated Multiwavelength Identification Scanner. Manual.
- Dolanjski, J.** 1983. Four Channel Filter Manual.
- Dolanjski, J.** 1983. Handbook Notes for Signal Conditioner.
- Dolanjski, J.** 1983. Handbook Notes for Cold Flume Profiler.
- Donelan, M.A. and W.J. Pierson** 1983. The Sampling Variability of Estimates of Spectra of Wind-Generated Gravity Waves. Journal of Geophysical Research, 88:C7, p. 4381-4392.
- Donelan, M.A. and S.A. Kitaigorodskii** 1983. Wind-Wave Effects on Gas Transfer. Proceedings of the International Symposium on Gas Transfer at Water Surfaces, Cornell University, Ithaca, N.Y. June 1983. D. Reidel Publ. Co.
- Donelan, M.A., J. Hamilton and W.H. Hui** 1983. Directional Spectra of Wind-Generated Waves. NWRI Unpublished Report. (Submitted to the Royal Society of London)
- Duncan, G.A.** 1982. Manual on Procedures for Stratigraphic Analysis of Unconsolidated Sediment Cores.
- Engel, P.** 1982. Characteristics of the WSC Basket Type Bed Load Sampler. NWRI Unpublished Report.
- Engel, P. and C. DeZeeuw** 1982. Calibration of the SIAP ME4001 Current Meter. NWRI Unpublished Report.
- Engel, P. and C. DeZeeuw** 1982. Étalonnage du moulinet SIAP ME4001. Rapport inédit, INRE.
- Engel, P.** 1982. (Discussion) Equivalent Roughness of Alluvial Bed. NWRI Unpublished Report. (Submitted to ASCE)
- Engel, P.** 1983. Sampling Efficiency of the VUV Bedload Sampler. NWRI Unpublished Report.
- Engel, P.** 1983. Critical Mean Velocity for Open Channel Flow over Coarse Bed Material. NWRI Contribution 83-14.
- Engel, P.** 1983. The Effect of Transverse Velocity Gradients on the Performance of the Price Current Meter. NWRI Contribution 83-15.
- Engel, P.** 1983. Performance Characteristics of the VUV Bed Load Sampler. NWRI Contribution 84-5.
- Ford, J.S.** 1983. Prototype Designs for Surveys and Measurement in an Aquatic Environment, 1980. IWD Technical Bulletin No. 123.
- Ford, J.S.** 1983. Prototypes d'appareils pour les études et mesures en milieu aquatique, 1980. Étude no 123, collection des rapports techniques, DGEI.
- Ford, J.S.** 1983. Prototype Designs for Surveys and Measurement in an Aquatic Environment, 1981. NWRI Contribution 83-11.
- Ford, J.S.** 1983. Prototypes d'appareils pour les études et mesures en milieu aquatique, 1981. Contribution no. 83-11 INRE.



**Ford, J.S.** 1983. Prototype Designs for Surveys and Measurement in an Aquatic Environment, 1982. NWRI Contribution 84-, (In press).

**Ford, J.S.** 1983. Prototypes of d'appareils pour les études et mesures en milieu aquatique, 1982. Contribution no. 84 — INRE, (Sous presse).

**Ford, J.A.** 1982. A Correction Technique for Sensors having Exponential Time Responses. NWRI Unpublished Report.

**Ford, J.S. and H. Savile** 1983. A Review of the Effects of Unsteady Flow Around Spherical Bodies. NWRI Unpublished Report.

**Ford, J.S.** 198 . Demonstration of a Correction Technique for Oxygen Profiler to Improve Spacial Information (In Press).

**Ford, J.S. and J. Dolanjski** 198 . A Sonde for Profiling having AC Power, and Bidirectional Microprocessor Communications on a Single Circuit (In press)

**Ford, J.S. and M.N. Charlton** 198 . An Oxygen Profiling System for Use on the Great Lakes (In press)

**Ford, J.S.** 1982. Operating Instructions (Preliminary) for the High Speed Oxygen Profiler. Manual.

**Ford, J.S., F.E. Roy and J. Dolanjski,** 1983. Technical Manual for the High Speed Oxygen Profiling System.

**Ford, J.S.** 1983. Operating Instructions for the Digital Oxygen Profiler. Manual. (In press).

**Harrison, E.J.** 1982. Handbook Notes for Portable Dissolved Oxygen Profiling System. Manual.

**Harrison, E.J.** 1982. Notes sur le système portatif servant à établir le profile des concentrations d'oxygène. Manuel.

**Harrison, E.J.** 1982. AWQUALABS Special Hardware Handbook Notes. Manual. Kitaigorodskii, S.A., **M.A. Donelan,** J.L. Lumley and E.A. Terray 1983. Wave — Turbulence Interactions in the Upper Ocean. Part 2. Statistical Characteristics of Wave and Turbulent Components of the Random Velocity Field in the Marine Surface Layer. Journal of Physical Oceanography, (In press).

**Krishnappan, B.G.** 1984. Laboratory Verification of a Turbulent Flow Model. Journal of the Hydraulic Engineering Proc. ASCE, 110:2.

**Krishnappan, B.G.** 1983. Suspended Sediment Profile for Ice-covered Flows. Journal of Hydraulic Engineering, ASCE, 109:3.

**Krishnappan, B.G.** 1983. Prediction of Bed Scour due to Constrictions in River Flows. Paper presented at the Workshop on Bridge Hydraulics held at Banff, Alberta, April 27-28, 1983.

**Krishnappan, B.G.** 1983. Formation of Meanders in Rivers. Paper submitted to the Journal of the Hydraulic Engineering, Proc. ASCE.

**Krishnappan, B.G.** 1983. MOBED- Users Manual Update. NWRI Unpublished Report.

**Krishnappan, B.G. and Y.L. Lau** 1982. User's Manual: Prediction of Transverse Mixing in Natural Streams, Model RIVMIX. NWRI Unpublished Report.

**Krishnappan, B.G.** 1983. Modelling of Unsteady Flow in Alluvial Streams. NWRI Unpublished Report. (Submitted to ASCE for publication)

**Lau, Y.L.** 1983. Suspended Sediment Effect on Flow Resistance. Journal of the Hydraulics Engineering Division, ASCE, 9:5, p. 757-763.

**Lau, Y.L.** 1983. River Mixing — State-of-the-Art Report. Canadian Journal for Civil Engineering, (In press).

**Marsalek, J.** 1984. Head Losses at Sewer Junction Manholes. Journal of Hydraulics Division, ASCE, 110:HY1, (In press).

**Marsalek, J.,** R.L. Rossmiller, B. Urbanas, and H.G. Wenzel 1983. Annotated Bibliography on Urban Design Storms. Urban Water Resources Research Council, ASCE, New York, N.Y.

**Marsalek, J.** 1983. SWMM Model and the Level of Discretization-Discussion. Jour. of Hydr. Div., ASCE, 109, (In press).

**Marsalek, J.,** D. Weatherbe, and G. Zukovs 1982. Institutional Aspects of Stormwater Detention. Proc. of the Engng. Foundation Conf. on Stormwater Detention Facilities, Hennikar, N.H. Aug. 1-6, 1982, p. 342-366.

**Marsalek, J. and W.E. Watt** 1983. Design Storms for Urban Drainage Design. Proceedings of the 6th Canadian Hydrotechnical Conference, CSCE, Ottawa, Ontario, June 2 and 3, 1983, p. 953-978.

**Marsalek, J.** 1983. Canadian Progress in Urban Hydrology Research (1979-1983). Proceedings of the International Symposium on Urban Hydrology, Baltimore, Md., May 1983, p. 1-18.

**Marsalek, J.** 1983. Temporal Distribution of Design Storm Rainfall. Proc. of the Seminar on Rainfall as the Basis for Urban Runoff Design and Analysis. Copenhagen, Denmark, August, 1983 (In press).

**Marsalek, J.** 1982. Road and Bridge Deck Drainage Systems. Research Report 228, Ministry of Transportation and Communications, Toronto, Ontario.

**Marsalek, J.** 1982. Design Parameters. Draft contribution to the UNESCO Manual on the Urban Drainage Design. NWRI Unpublished Report.

**Marsalek, J.** 1983. Urban Runoff Peak Frequency Curves. NWRI Unpublished Report.

**Marsalek, J.** 1983. Contribution to the ASCE Manual of Practice on Design and Construction of Storm Drainage Systems. NWRI Unpublished Report.

**Marsalek, J. and B. Greck** 1983. Toxic Substances in Urban Land Runoff in the Niagara River Area. NWRI Contribution 83-17.

**Marsalek, J.** 1983. Characterization of Runoff from an Urban Commercial Area. NWRI Unpublished Report.

**Marsalek, J.** 1983. Caractérisation du ruissellement de surface à partir d'une zone urbaine commerciale. (Submitted for publication Sciences et techniques de l'eau)

**Marsalek, J. and G. Patry.** Urban Design Floods. Chapter 7 (draft), The Design Flood Guide for Canada. In preparation.

Martini, I.P., **N.A. Rukavina** and J.K.P. Kwong 1982. Resource Potential of Lake Ontario Nearshore Deposits. Proceedings, Third Workshop on Great Lakes Coastal Erosion and Sedimentation, Burlington, Ontario, November 1982, p. 149-152.

Mudroch, A., **A.J. Zeman** and L.L. Kalas 1982. Calcium Carbonate in Postglacial Lake Erie Sediment. Journal of Great Lakes Research, 8:4, p. 711-718.

**Ng, H.** 1982. Some Preliminary Results of Variations of Rainwater Chemistry Within Storm at Blair Road Site in Burlington. NWRI Unpublished Report.

**Ng, H. and J. Marsalek,** 1983. Energy Losses at Junction Manholes with a Lateral. Unpublished Report.

**Pashley, A.E. and P. Carney** 1982. Apparatus for Extracting Invertebrates from Peat. NWRI Unpublished Report.

**Pashley, A.E. and R. Boucher** 1982. De-oxygenation Chambers for Interstitial Water Sampler (PEEPERS). NWRI Unpublished Report.

**Pashley, A.E. and P. Carney** 1982. Foot Operated Hydraulic Core Extruder. NWRI Unpublished Report.

**Pashley, A.E. and P. Carney** 1982. Natural Convection Tank. NWRI Unpublished Report.

**Pashley, A.E. and P. Carney** 1982. Sediment Respiration Domes. NWRI Unpublished Report.

**Pedrosa, M.** 1982. Field Portable Embryo Motion Detector. NWRI Unpublished Report.

**Pedrosa, M.** 1982. Détecteur portatif de mouvements de l'embryon. Rapport inédit INRE.

**Roy, F.E.** 1983. A General Automatic Profiling System for Great Lakes Applications. Proceedings, 1983 MTS/NDBP Buoy Technology Symposium, 27-29 April 1983, New Orleans, LA, U.S.A., p. 265-271.

**Roy, F.E.** 1982. Fixed Temperature Profiler Improvements Phase A Report. NWRI Unpublished Report.

**Roy, F.E. and P. Carney,** 1982. Modification of Wetfall Rain Sampler for Application to Snowfall Sampling. NWRI Unpublished Report.

**Roy, F.E.** 1983. Spring Exchange Flows, Black Bay, Lake Superior. NWRI Unpublished Report. (Submitted to the Journal of Great Lakes Research).

**Roy, F.E.** 1982. Manual for FTP Support Buoy.

**Roy, F.E.** 1982. Manuel pour la bouée PTPF de soutien.

**Rukavina, N.A.** 1982. (Editor) Proceedings, Third Workshop on Great Lakes Coastal Erosion and Sedimentation, National Research Council, Burlington, Ontario, November 1982, 177 p.

**Rukavina, N.A.** 1983. Lake Erie Nearshore Sediment Data, Port Glasgow to Long Point, Ontario. NWRI Unpublished Report. (Restricted Distribution)

**Rukavina, N.A.** 1983. Data on Nearshore Sand and Gravel Deposits in Lake Ontario. NWRI Unpublished Report. (Limited Distribution)

**Rukavina, N.A.** 1983. Data on Nearshore Sand and Gravel Deposits in Lake Erie. NWRI Unpublished Report. (Limited Distribution)

**Savile, H.** 1982. Resuspended Sediment Sampler. NWRI Unpublished Report.

**Savile, H.** 1982. The Development of a Through-the-Ice Water Sampler. NWRI Unpublished Report.

**Savile, H.** 1982. Design and Construction of a Miniature Aqueous Phase, Liquid Extractor System (A.P.L.E.). NWRI Unpublished Report.

**Savile, H.** 1982. Conception et construction d'un petit système d'extraction de liquide en phase aqueuse (E.L.P.A.). Rapport inédit, INRE.

**Savile, H.** 1982. Portable Centrifuge for Field Use. NWRI Unpublished Report.

**Savile, H.** 1983. A Stress Analysis of Transmissometer Windows. NWRI Unpublished Report.

- Savile, H.** 1983. Aqueous Phase Liquid-Liquid-Extractor (A.P.L.L.E.). NWRI Unpublished Report.
- Savile, H.** 1984. Reaction Vessels. NWRI Contribution 84-11.
- Savile, H.** 1984. Two-Phase Interface Exciter. NWRI Contribution 84-12.
- Schweb, D.J., J.R. Bennett, P.C. Lui, and **M.A. Donelan** 1983. Application of a Simple Numerical Wave Prediction Model to Lake Erie. GLERL Contribution No. 382. (Submitted to the Journal of Geophysical Research)
- Skafel, M.G.** 1983. Sinclair Cove: A Physical Model Study of Wave Agitation. Proceedings Canadian Coastal Conference, Vancouver, B.C., May 12-13, 1983, p. 269-282.
- Skafel, M.G.** and **M.A. Donelan** 1983. Performance of the CCIW Wave Direction Buoy at ARSLOE. IEEE Journal of Oceanic Engineering. OE-8:4, p. 221-226.
- Skafel, M.G.** and **B.G. Krishnappan** 1983. Suspended Sediment Distribution in a Wave Field. ASCE Journal of the Waterway, Port, Coastal and Ocean Division, (In press).
- Skafel, M.G.** 1982. The Motion Package Buoy at ARSLOE: Data Summary. NWRI Unpublished Report.
- Tsang, G.** 1983. Formation and Properties of Frazil Seawater at Different Supercoolings. Proceedings of Conference of Port and Ocean Engineering under Arctic Conditions. (POAC), April 5-9, 1983, Helsinki. (In press).
- Tsang, G.** and T. Hanley 1982. Formation and Properties of Frazil in Saline Water. Journal of Cold Regions Science and Technology, (In press).
- Tsang, G.** 1982. Modelling Criteria for Bubble Plumes — A Theoretical Approach. NWRI Unpublished Report. (Submitted to CJCE for publication)
- Tsang, G.** 1982. Darlington NGS Cooling Water Intake Risk Evaluations for Frazil Blockage. NWRI Unpublished Report.
- Tsang, G.** and **M. Pedrosa** 1983. Development and Calibration of the NWRI Frazil Instrument. NWRI Contribution 83-16.
- Tsang, G.** and **M. Pedrosa**, 1983. Electronic and Mechanical Design of the NWRI Frazil Instrument. NWRI Unpublished Report. (Limited Distribution)
- Tsang, G.** and T. Hanley, 1983. Frazil Formation in Water of Different Salinities and Supercoolings. NWRI Unpublished Report. (Submitted to the Journal of Glaciology)
- Tsang, G.** 1983. An Instrument for Measuring Frazil Concentration. NWRI Unpublished Report.
- Valdmanis, J.** and **H.A. Savile** 1983. Manual for 1983 Under-Ice Video System.
- Watson, A.S., F.E. Roy** and **J. Dolanjski** 1982. Landsat — Compatible Shipboard Radiometer System. NWRI Unpublished Report.
- Watson, A.S.** 1982. A Flume Contour Profiler for Tracking and Measuring Flume Bed-Level and Water-Level Variations in Time or Space. NWRI Unpublished Report.
- Watson, A.S.** 1982. Conceptual Opportunities for Improved or Advanced Surveillance Instrumentation System. NWRI Unpublished Reports.
- Watson, A.S.** 1983. A "BASIS" (Buoy for Air/Sea Interface Sensing). NWRI Unpublished Report.
- Watson, A.S., F.E. Roy** and **J. Dolanjski** 1982. Handbook Notes for Shipboard Radiometer System. Manual.
- Weatherbe, D., **J. Marsalek** and G. Zukovs 1982. Research and Practice in Urban Runoff in Canada. Jour. of TCOR, ASCE, 108:TC2, p. 226-240.
- Wong, J., S. Beltaos** and **B.G. Krishnappan** 1983. Laboratory Tests on Ice Jam Dynamics. NWRI Contribution 83-13. (Submitted to CJCE for publication)
- Wong, J.** and **S. Beltaos**, 1983. Ice Freeze Up and Breakup Observations in the Upper Grand River: 1980-81 and 1981-82 Observations. NWRI Contribution 84-2.
- Zeman, A.J.** 1983. Erosion of Cohesive Sediments — Bibliography and Annotated Abstracts. NWRI Unpublished Report, 92 p.
- Zeman, A.J.** 1982. Stratigraphy and Textural Composition of Bluff Soil Strata, North Shore of Lake Erie between Rondeau and Long Point. NWRI Unpublished Report. (Restricted distribution)
- Zeman, A.J.** 1982. Erosion Resistance of Cohesive Sediments. Proceedings, Third Workshop on Great Lakes Coastal Erosion and Sedimentation, NRC, Burlington, Ontario, November 1982, p. 93-96.
- Zukovs, G., D. Weatherbe, and **J. Marsalek** 1982. Urban Runoff Control Technology. Civil Engineering-ASCE, 52:8, p. 50-52.



## NWRI PACIFIC AND YUKON REGION

The Pacific and Yukon Regional branch of NWRI, located in West Vancouver, B.C., conducts applied research related to regional water management problems. It has traditionally used a multidisciplinary approach to develop an understanding of how regional limnological systems function. Ultimately an attempt is made to predict the ecological sensitivity and response of regional lakes and rivers to the application or removal of such anthropogenic environmental stresses as nutrient-rich effluent loadings, industrial waste discharges, placer-mine wastes, acidic and metal-rich mine drainage and tailings, hydro-electric reservoir construction and operation, and large-scale inter — or intra-basin diversions.

The geomorphologic uniqueness of this region defies easy transfer of conclusions drawn from the study of lake systems in the prairie or shield areas of Canada. Most of the lakes in B.C. and the Yukon are long, narrow and deep, and are strongly influenced by riverine flows. All have marked seasonal water-level fluctuations, especially those

lakes that are used as storage reservoirs for hydro-electric power generation.

In the past the branch concentrated on single issues of regional importance, prompted either by public political protest, federal-provincial agreement in response to public consultation, or by direct government initiative. More recently, however, the regional research focus has shifted to a wider spectrum of studies reflecting the diversity of environmental issues and ecological problems in the region. Research is currently being directed at three broad environmental issues: river eutrophication, hydro-electric developments (especially in the north), and lake restoration and eutrophication.

**River Eutrophication: Thompson River Benthic Algae.** A joint research project with Weyerhaeuser Canada Ltd. in 1979-1981 examined the causes of excessive benthic algal growth in the Thompson River downstream of Kamloops Lake (Fig. 1). Using continuous flowing troughs to deter-

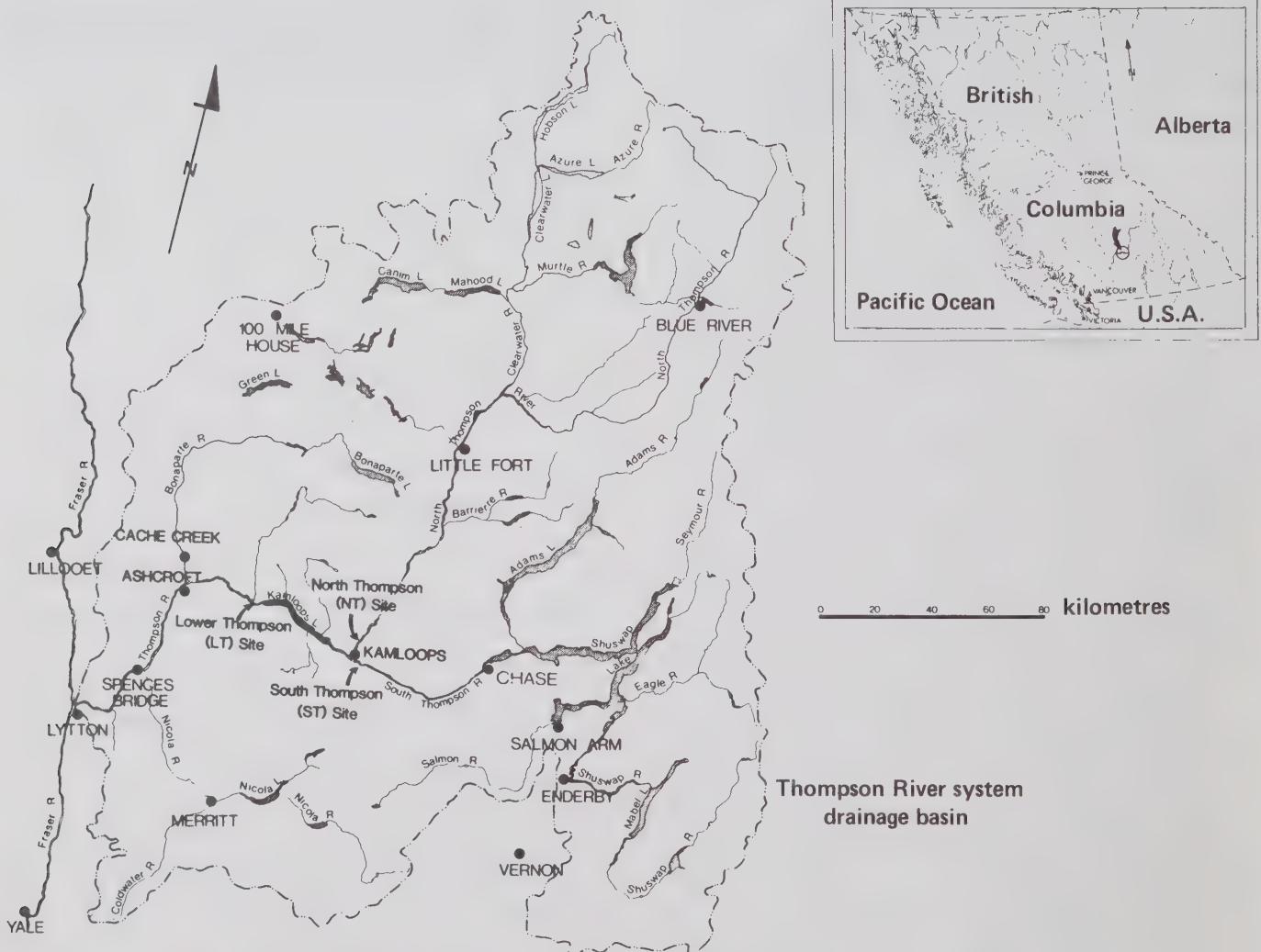


Figure 1 Map showing location of the Thompson River 1979-81 study sites LT, NT and ST, and the present field site at Chase.

mine algal growth rates and physiological status, evidence was collected that benthic algal growth rates were faster downstream of the lake compared with upstream. In addition, the phosphorus nutrition of the downstream algae was found to be considerably better.

The methodology and results of this project have been compile into three publications. A detailed description of the continuous-flow trough methodology and its adaptation for use in sub-zero weather was given. An extension to the methodology that incorporates the use of dark trough controls was reported. Using dark troughs it was possible to correct light trough accumulation for passive settlement of algae. The resultant net growth rate estimates were as low as one-third of unadjusted estimates. The final publication provides a detailed examination of the data from this two-year project. Despite the low river temperatures during most of the study (1- 6°C) all three experimental sites showed algal growth rates limited by phosphorus. Using a suite of chemical and physiological tests, differences in the three algal populations could be distinguished even though the phosphorus concentrations at the three sites were similar and very low (SRP levels: zero to 1-2 ppb at the two upstream sites and zero to 3 ppb at the downstream site).

A continuation of this research involved a second joint project with Weyerhaeuser Canada Ltd., signed in the summer of 1982. This project, in operation now, will attempt to assess the relationship between benthic algal growth rate and concentration of the limiting nutrient, phosphorus. Other parameters such as temperature, light, and current velocity (thought to be interactive with phosphorus concentration in controlling growth rates) will also be examined.

The first phase of the project was to select a site on the Thompson River system that could deliver clear, low-phosphorus water. A location at Chase near the outlet of Little Shuswap Lake (Fig. 1) was chosen. The second phase

involved construction of a multiple 12-trough facility (Fig. 2) and establishing a field laboratory at the site. This will allow physiological tests and growth rate measurements to be determined over a range of phosphorus levels. Light intensity and current velocity in each trough can be controlled independently and the experiments will be conducted year-round to investigate effects of temperature.

The next two years will involve data collection, analysis and documentation of the results from this study. (*Bothwell, Jasper*)

**Northern Hydro Limnology: The Yukon River Headwater Lakes.** Results obtained to date in this project have necessitated changes to the original plan. The project is now considered to be primarily a physical limnology and sedimentology study. The chemistry and biology sampling and analysis showed that productivity was relatively low and the nutrient concentrations were at times at the limit of detection (Fig. 3).

Detailed bathymetric charts and compilations of morphometric and hydrologic parameters of Lakes Laberge, Marsh, Tagish and Bennett have been completed and are available in a regional IWD report (Pharo, 1984). Surface sediment samples and some cores from Lake Laberge have been analysed for sedimentological and geochemical compositions and that data is available in an in-house data report (Chamberlain and Pharo, 1984). Cores collected at intervals along the lengths of the other lakes are now being examined.

An experimental attempt is being made to understand and to define the dynamic processes affecting intra-lake sediment transport and deposition in Lake Laberge and in Kluane Lake. Sediments entering Lake Laberge are carried through the lake via a buoyant, surface overflow. In Kluane Lake, by contrast, the inflowing river water is of such high sediment concentration that transport is effected by sub-surface turbidity currents. While through-lake transport in

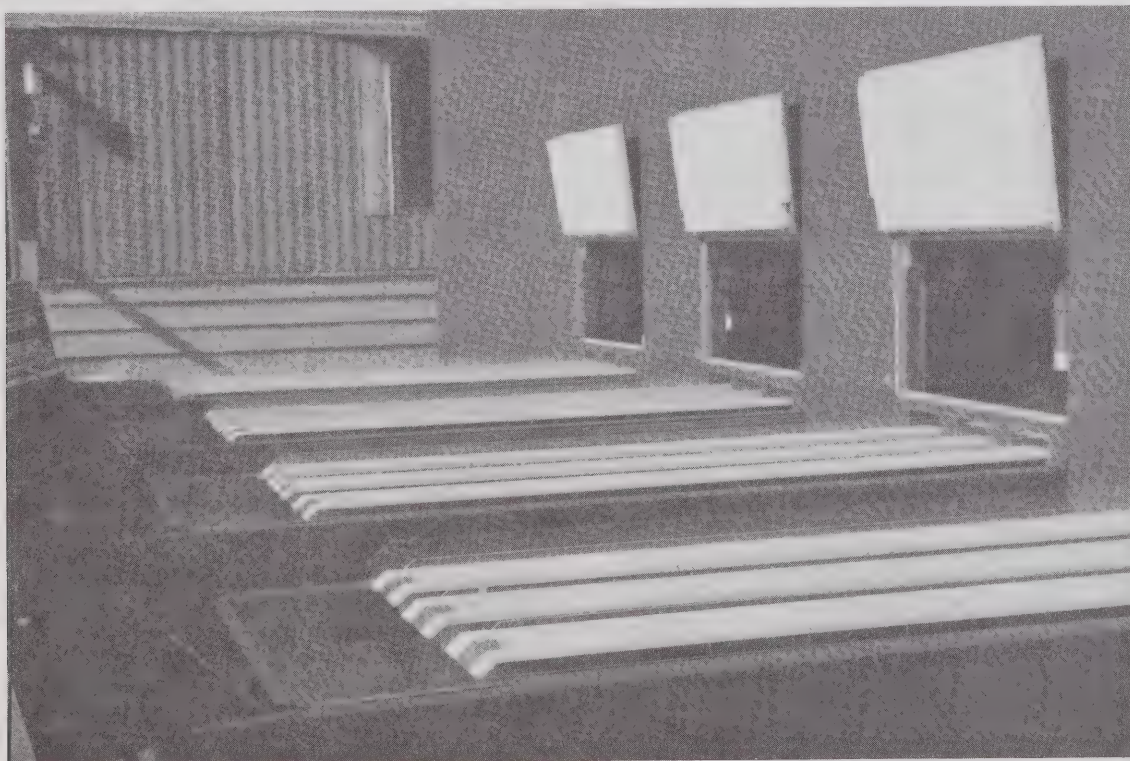


Figure 2 Multiple trough facility for periphyton.



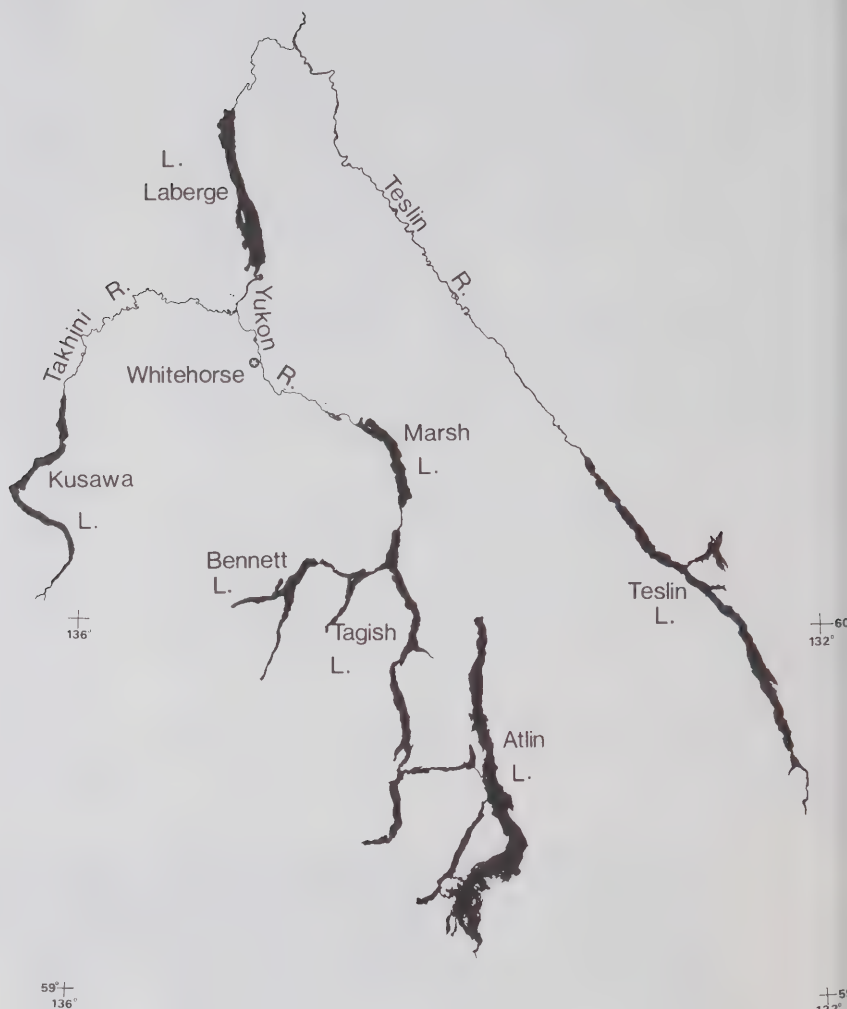
62°+  
139° 30'

136°

62°+  
132°



60°+  
139° 30'



**Figure 3** The Yukon River headwater lakes in southern Yukon and northern British Columbia.

Lake Laberge takes place within a geostrophically-controlled boundary current along the eastern shoreline of the lake, the cross-lake movement of particulate material (and thus the underwater light climate) may be influenced by barotropic instabilities. In the case of Kluane Lake, the key to understanding sediment transport seems to lie in defining the processes that occur along the lake-river front: e.g. the transition from river flow to turbidity current. (Pharo, Carmack)

To obtain a general description of physical seasonality, a limnological transect, consisting of temperature/salinity/depth profiles, was flown from Atlin Lake through Tagish, Marsh, and Laberge lakes. Although these lakes belong to the same river system, their residence times, suspended sediment concentrations, and source water characteristics all vary widely, thus providing an excellent system for comparative studies. Flights were made in summer, 1981; in winter, spring, summer, and fall, 1982; and in the winter of 1983. Initial examination of the data suggests that the intra-seasonal evolution of water masses within individual

lakes may provide a means for determining dominant circulation patterns.

Additional seasonal data is being collected from moored, self-recording instruments in Lake Laberge, instruments in Lake Laberge, including a meteorological station, thermographs at both the inlet and outlet, and three thermistor chains. Since these instruments record data at 30-90 minute intervals, they should yield the kind of information on mixing processes required to formulate and calibrate representative physical models of northern lake-river systems. An early finding of these data is that spring overturn in Lake Laberge is initiated by the inflow of the Yukon River, and that this river-driven ventilation process first affects the mid-depth layers of the lake before moving progressively downwards. This mechanism will influence the lake's heat balance during ice break-up, and dominate the lake's flushing characteristics throughout spring.

A major change to the original plan and addition to the physical limnology program is a joint study with Water Resources Branch Pacific and Yukon Region, to document

and interpret the seasonal ice cycle from the point of view of lake-river interaction. Its objectives are to describe the ice dynamics of an upstream river, the influence of that river on the ice cover and temperature structure of a recipient lake, and the effects of lake outflow on ice conditions in a downstream river. Lake-river interactions have been largely ignored in past studies on ice behaviour, but such an approach is necessary to understand the consequences of reservoir construction and operation in northern latitudes. The study area for this experiment consists of the Yukon River from Whitehorse to lake Laberge, the lake itself, and the Yukon River immediately downstream of Lake Laberge. Data on the lake is being obtained both by self-recording instrumentation and by means of conductivity/temperature/depth surveys carried out from snowmobile and ski-plane. Studies on the upper and lower rivers are largely concerned with evolution of ice cover and its relationship to hydraulics. One promising outcome of this work will be the ability to compute changes with time in the composite resistance of the river reach immediately below Schwatka Reservoir in the presence of an advancing ice front. Another goal of the Lake Laberge experiment is to gain a quantitative understanding of the formation of outlet polynyas, as these large, ice-free areas provide an essential bird habitat. In addition, a combined ice-cover/thermal structure model is currently being developed at NWRI-Burlington. Our data will be used to refine, calibrate, and verify this model for generational use on ice-covered lakes and reservoirs. (*Carmack, Kirkland, Gray*)

**Lake Restoration and Eutrophication: The Southern Lakes.** Work done under this project involved finishing projects on Wood Lake in the Okanagan Valley, completing a diffuse nutrient loading study in the Okanagan, as well as testing and refining a suspended-sediment/nutrient collecting and analysis methodology. The biologically available portion of the nutrients supplied to Okanagan Valley lakes by streams and rivers was evaluated by chemical analysis of water and suspended material. Biologically available phosphorus (BAP) varied between 16% and 98% of total P while the biologically available nitrogen (BAN) varied from 56% to 98% of the total N. (*Gray, Kirkland*)

The Pacific and Yukon Regional Branch of NWRI has also been involved in such major referrals as the Okanagan Basin Implementation Board Implementation Agreement and the Thompson River Task Force on proposed effluent discharges from the city of Kamloops into the Thompson River. Scientists on staff have reviewed and refereed numerous journal papers, proposals, and grant requests, and have acted on student thesis advisory committees. Specialist advice and consultation has been extended on request to other branches of IWD, Environment Protection Service, Fisheries and Oceans, Energy, Mines and Resources, and to the Ministry of Environment of the Province of B.C.

## STAFF LIST

**Branch Chief (Acting) — Dr. C.H. Pharo**  
**Office Manager — Ms. S.E. Roberts**

### Researchers

Dr. M.L. Bothwell	river ecology
Dr. E.C. Carmack	physical limnology
Dr. R.J. Daley	microbial limnology
Mr. C.B.J. Gray	chemical limnology
Mr. S. Jasper	biological limnology
Mr. R.A. Kirkland	chemical limnology
Mr. R.C. Wiegand	physical limnology

### Technical Staff

Ms. V.A. Chamberlain  
 Mr. E.W. Marles  
 Ms. K.E. Suzuki

## COMMITTEE MEMBERSHIP

C.H. Pharo  
 Regional IWD Health and Safety Committee —  
 Chairman

DOE Diving Safety Committee

R.C. Wiegand  
 Regional EDP Users Committee

## PUBLICATIONS

*Bothwell, M.L.* 1983. All-weather Troughs for Periphyton Studies. *Water Res. Res.*, 17: 1735-1741.

*Bothwell, M.L.* Phosphorus Limitation of Lotic Periphyton Growth Rates: An Intersite Comparison Using Continuous-flow Troughs (Thompson River system, B.C.). *Limnology and Oceanography*, (In press).

*Bothwell, M.L.* and *S. Jasper* 1983. A Light and Dark Trough Methodology for Measuring Rates of Lotic Periphyton Settlement and Net Growth. IN: R.G. Wetzel (Ed.) *Periphyton of Freshwater Ecosystems*. Developments in Hydrobiology, Chapter 31: 235-265. W. Junk, publishers.

*Carmack, E.C.* Circulation and Mixing in Ice-covered Waters. IN: N.J. Untersteiner (Ed.) *Air-Sea-Ice Interaction*, NATO Advanced Studies Institute Series, Plenum.

*Carmack, E.C., R.C. Wiegand, C.B.J. Gray, C.H. Pharo, R.J. Daley* and *S. Jasper*. On Mechanisms Influencing the Riverine Circulation and Distribution of Water Masses in a Medium Residence-time Lake, Kootenay Lake, British Columbia. *Limnol. Oceanogr.*, (In press).

*Chamberlain, V.A.* and *C.H. Pharo* 1984. Lake Laberge, Y.T. Sedimentology and Geochemistry. Unpublished Report. NWRI Pacific and Yukon Region, Vancouver, B.C.

*Gray, C.B.J.* and *R.A. Kirkland* 1982. Nutrient Composition and Bioavailability in Major Tributaries and Interconnecting Rivers of the Okanagan Basin. IWD Regional report, Vancouver, B.C. 127 pp.

*Gray, C.B.J.* and *S. Jasper* 1982. Limnological Trends in Wood Lake, B.C. (1971-1981), with some Implications for Lake Management. IWD Regional report, Vancouver, B.C. 21 pp.

*Jasper, S.* and *C.B.J. Gray* 1982. The Chemical and Microbiological Limnology of Wood Lake, B.C. IWD Regional report, Vancouver, B.C. 60 pp.

*Jasper, S., R.J. Daley, C.B.J. Gray, C.H. Pharo, E.C. Carmack* and *R.C. Wiegand* 1983. Primary Productivity in a Large Temperate Lake with River Inflow: Kootenay Lake, B.C. *Can. J. Fish. Aquat. Sci.*, 40:3 319-327

*Luternauer, J.L., J.J. Clague* and *C.H. Pharo* 1983. Substrates of the Strait of Georgia, British Columbia. *Can. J. Fish. Aquat. Sci.*, 40:7 1026-1032.

*Luternauer, J.L., J.J. Clague, C.H. Pharo, T.M. McGee* and *R.H. Linden*. Geology of the Strait of Georgia, B.C. *Can. J. Earth Sci.*, (In press).

*Wiegand, R.C., E.C. Carmack, R.J. Daley, C.B.J. Gray, S. Jasper* and *C.H. Pharo* 1982. Seasonal Aspects of the Surface and Advective Heat Fluxes of Kootenay Lake, B.C. *Water Res. Res.*, 18: 1493-1502.



## NWRI WESTERN AND NORTHERN REGION

This branch of the National Water Research Institute was established to serve the research needs of a region which extends across the three prairie provinces and the Northwest Territories. Whereas water quality issues in the Great Lakes have historically dominated water resource management concerns in Canada, this pattern is changing. Success in managing nutrient problems in the Great Lakes, together with an increasing emphasis on economic growth in Western Canada, are causing renewed national attention to the historic water supply-demand imbalances in this Region and the generally poor quality of water in many prairie communities. Potential expansion of irrigated and dryland agriculture, increasing demand for water diversions, and the continued development of resource industries and related industrial complexes, are raising serious concerns over water supply and the potential problem of toxic chemicals in western drainage systems. Additionally, potential megaprojects in the Mackenzie River Basin are generating concern over the future of northern drainage systems. These developments are occurring at a time when the federal government is espousing the principles of sustained development with maintenance of ecological stability.

The past year focus was on the rivers and lakes of the Qu'Appelle Valley in Saskatchewan, the Churchill Diversion from South Indian Lake and its related reservoirs in Northern Manitoba, the North Saskatchewan River system and the Wabigoon-English River system. Our activities have been balanced amongst the practical concerns of toxic substances, the severe prairie problem of excessive enrichment of surface waters, and the fundamental understanding of nutrient and contaminant behaviour in prairie rivers and lakes. This blend of research achieves the dual objective of appropriate response to regional concerns and the increase of knowledge necessary to meet the long term objectives of DOE in this region.

### THE QU'APPELLE RIVER SYSTEM

**Phosphorus Dynamics.** Phosphorus is a dynamic variable in lakes. Previous attempts to evaluate phosphorus in lakes using the assumption of static equilibrium have been shown to be inadequate and/or incorrect. Lake phosphorus concentrations fluctuate as a forces response to changes in the inflow phosphorus concentrations. Using mean annual inflows the time varying phosphorus concentration was accurately simulated for Lake Washington for the entire period for which published data are available (1962-1978). The use of monthly mean data (1970-1978) improved the simulation of phosphorus concentrations in Lake Washington and provided substantial insight into the effects of the 1972 and 1975 floods. The simulation of phosphorus concentrations in the four Qu'Appelle Lakes required extension of the dynamics concept to account for high prairie evaporation, precipitation and variable lake levels. It was found that three time scales were necessary to dynamically describe this chain of four lakes: the phosphorus inflow time scale, the phosphorus inflow time scale and the sedimentation time scale. Using a time series of instantaneous inflow concentrations that were available at random times from 1970 together with the 72 hour composite data collected by WQB from 1980-1983, the lake phosphorus concentrations were accurately simulated for the Qu'Appelle Lakes. The results suggest

that not net sedimentation occurs and that the lakes are saturated with respect to phosphorus. (Kenny)

**Palaeolimnology of Pasqua Lake.** The study of the palaeolimnology of Pasqua Lake was originally initiated to determine the impact of cultural development on the historical trophic state of the downstream Qu'Appelle River lakes by interpreting the succession of larval chironomid (Chironomidae:Diptera) remains in the sediments. Initial analysis of contemporary chironomid communities, however, indicated that contaminants may also be a problem in the lakes. Sampled to provide baseline data for the palaeo-study, the surviving chironomid fauna display varying degrees of morphological deformities.

Analysis of the sub-fossil fauna from Pasqua Lake indicate (Fig. 1a) that members of a shallow-water lake community dominated by species of *Chironomus* (Meig.) have dominated the fauna throughout the period of history (ca. 300 years) defined in the sediments of Core P-7-M. Prior to colonization, the trophic state of the lake varied between eutrophic (TIN 13) and strongly eutrophic (TIN 14). The increase in organic loadings coincident with the beginning of colonization (Fig. 1b) indicate that the input of nutrients from cultural sources has increased the productivity of the lake. The interpretation is difficult to confirm from the faunal record, because the more recent chironomid communities have been decimated. The increase in eutrophy,, possibly to conditions of gross eutrophy (TIN 15), may account for the decline in fauna but the effects of contaminants, magnified by already severe trophic conditions, probably were the crucial determining factor. (Warwick)

**Toxic Substances.** A two year study of biogeochemical pathways of methylated and unmethylated mercury and other heavy metals and their seasonal and sit-related variations in the Qu'Appelle system is to be completed in 1984. Samples of water, suspended and bottom sediment, and biological material were collected at different seasons at many different sites extending from the cities of Moose Jaw and Regina downstream to the Qu'Appelle River beyond Round Lake. The data suggests that the mercury is mainly derived from sources of pollution in Moose Jaw and Regina. Although the ecological effects of mercury (for instance, accumulation by fish) tend to decrease in the downstream direction, seasonal and site-specific factors complicate the picture. For instance, in one sampling season total mercury levels in water were highest near the sources of pollution, but methyl mercury levels were highest further downstream, probably owing to enhanced microbial growth resulting from introduction of nutrients by tributary waters. Elevated primary production apparently stimulates methylation of mercury. (Jackson, Ongley)

### SOUTH INDIAN LAKE (SIL)

**Winter Circulation.** The effect of impoundment on SIL is being studied by DFO using water and nutrient budgets from an adjoining bay, Long Bay. Vertical temperature profiles along the axis of Long Bay suggest the presence of an under-ice circulation that theoretically could dominate the water renewal time in the bay with concomitant impact on the budget studies. An ultra low velocity (ULV) current meter was designated and constructed to directly measure



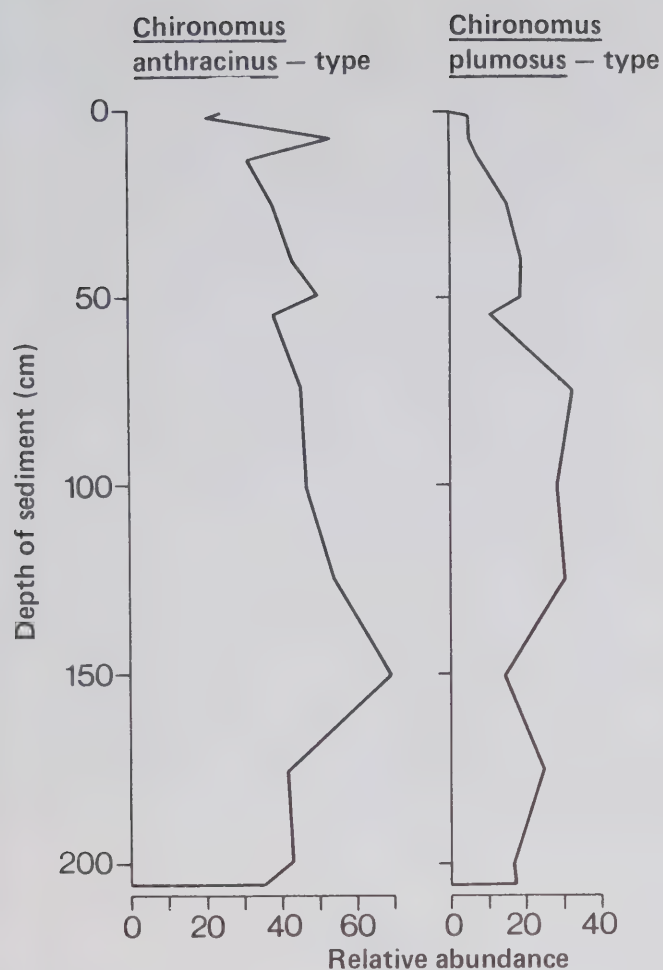


Figure 1a Sub-fossil fauna from Pasqua Lake.

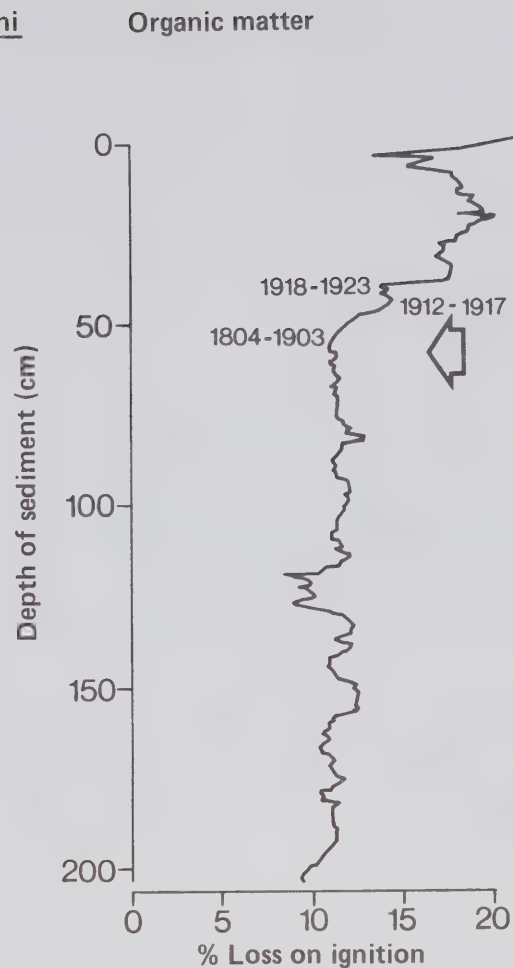


Figure 1b Organic content of sediments in Pasqua Lake.

the flow in the narrow strait joining Long Bay to SIL. Highly variable currents in excess of 1 cm/s were measured. Temperature fluctuations accompanying the two layer flow are intense and show large changes in the thermal structure over a short period (Fig. 2). Winter circulation is likely to dominate water renewal in all embayment with similar morphometry. (Kenney)

**Toxic Substances.** A study was initiated in 1981 to determine the bioaccumulation and transfer of mercury from the reservoir sediment through the food chain to the upper level carnivores, fish and man. The purpose is to investigate effects of environmental alteration due to impoundment on the speciation and bio-availability of mercury. Samples from the sediments, water, plankton and benthic communities as well as shoreline plants and soil were collected from two sites (Long and South bays) in South Indian Lake and three sites (Rat, Mynarski and Notigi lakes) in the new Notigi reservoir for analysis and especially for utilization in experiments.

The individual components were analyzed for methyl and total mercury and other trace metals; the sedimentary environment was defined by primary ignition analysis and particle-size measurements. A series of laboratory experiments on methylation and demethylation of mercury by

microbes in the bottom sediments under different environmental conditions have yielded encouraging results. Our findings are in agreement with data gathered independently by DFO and indicate major regional differences in the abundances and biogeochemical behaviour (chemical speciation and bio-accumulation) of mercury, as well as some important seasonal variations. The regional pattern of variation is related to environmental changes caused by shoreline flooding resulting from impoundment, and the same basic pattern is discernible in the samples collected in 1983. A final report of the results is in progress.

In the summer of 1982 a project on the effects of humic matter on iron nutrition and primary productivity in Southern Indian Lake was undertaken in collaboration with DFO. This continues an earlier study where we advanced the hypothesis that humic matter in the water inhibits primary production by sequestering iron. Subsequent field experiments by DFO have yielded data which appear to confirm this conclusion. (Jackson, Warwick)

## THE NORTH SASKATCHEWAN RIVER SYSTEM

This study, originally known as the Tobin Lake Study, seeks to establish the dynamics of contaminant transport

processes within the North Saskatchewan system and to develop an ecotoxicological approach for measuring the effects of contaminant input to Tobin Lake. Participants in the study include EPS, University of Manitoba and NWRI.

Tobin Lake, because of its location well downstream, integrates the input of toxic substances from most of the river basin. Ecotoxicology in the lake has been examined over the past several years, (i) to develop workable chemical fractionization scheme and biological assay protocol which would permit rapid and cost-effective screening for groups of similar organic contaminants and, (ii) to examine impact of toxic substances on in-situ benthic organisms.

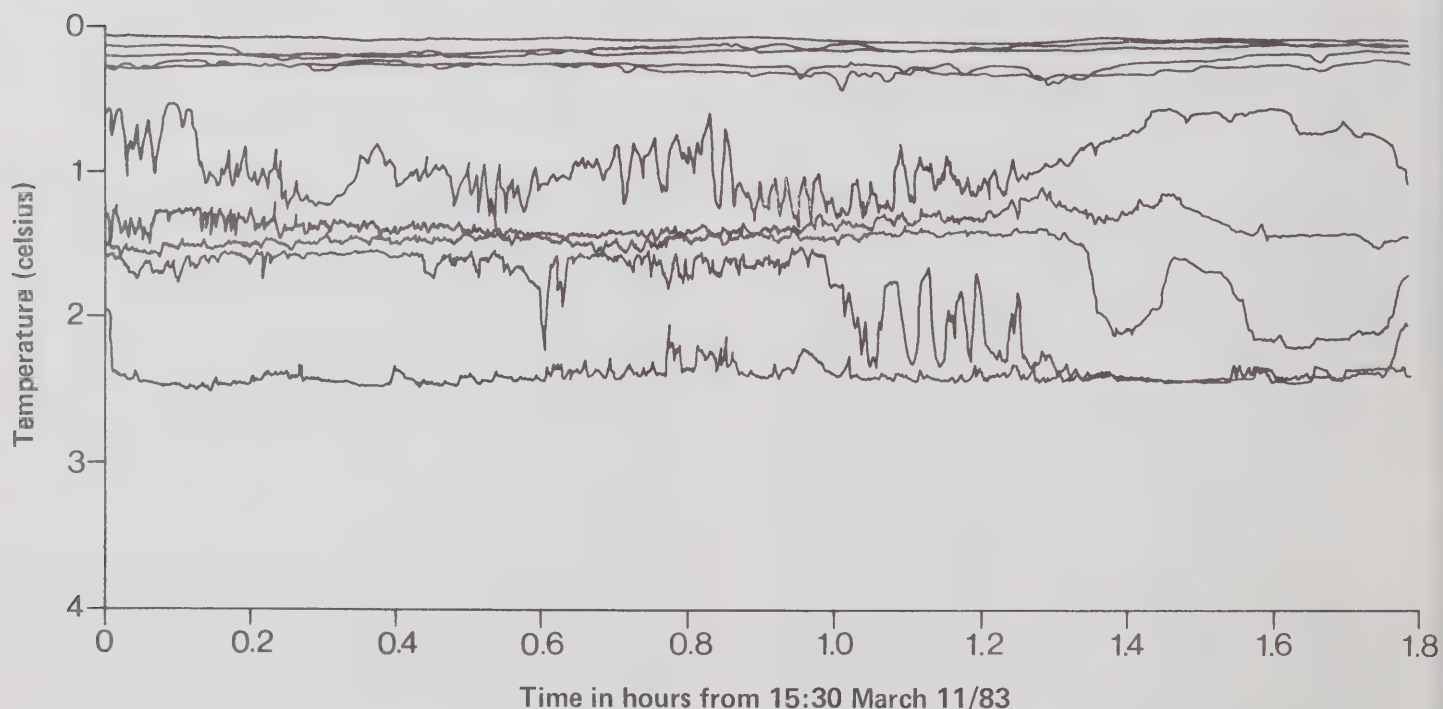
Objective (i) was achieved and is now in place in the regional organic contaminants laboratory of EPS. Results from bottom sediments indicate that a range of organic contaminants have reached Tobin Lake which have mutagenic and, in some instances, lethal effects on lower members of the food web. It is not now known where these chemicals originated, whether they are diffuse or point source in origin, under what circumstances these were delivered to Tobin Lake, nor whether there is any impact on higher forms of life. Suspended sediment samples taken from various sites on the North Saskatchewan River during a summer storm event in July of 1981, indicate a complex set of sources and pathways for organic contaminant transport in the North Saskatchewan. These may involve point and diffuse sources as well as spatial and temporal effects. Sources, transport mechanisms and fate of organic contaminants are currently under investigation at nine locations starting upstream of Edmonton. (*Ongley, Warwick*)

## WABIGOON-ENGLISH RIVER SYSTEM

The final report of the Canada/Ontario study presenting resulting of the second year's research and a summary of final conclusions and recommendations covering the entire project was completed.

A laboratory project that deals with synergistic and antagonistic effects of copper, cadmium, and zinc on the biomethylation of mercury by microbes in Clay Lake and Wabigoon River sediments was completed in 1982. With increasing concentration of Cu(II), Cd(II), or Zn(II) chloride in a sediment-water slurry containing added Hg(II) chloride, methylation is progressively inhibited until a threshold concentration is reached, after which there is a large increase in methyl mercury. These results are interpreted as representing ecological succession among different species or strains of methylating microbes. At lower metal concentrations, the more metal-sensitive methylating microbes are inhibited, but at higher levels relatively metal-tolerant methylating microbes, which had been suppressed by the more sensitive ones at lower metal levels, rise to a position of dominance in the microbial community. Analysis of sediments from different lakes near Flin Flon showed that this process is probably occurring in nature. Effects of different sedimentary materials were also examined.

A laboratory project on the availability of methyl mercury to trout fry under various controlled conditions (for instance, in the presence and absence of different kinds of particulate matter) has also been completed. Preliminary evaluation of results suggest inhibition of methyl mercury uptake under certain conditions. (*Jackson*)



**Figure 2** Inverse stratification under ice in Long Bay, South Indian Lake. Temperatures were measured at depths of 1.4, 2.4, 2.9, 3.4, 4.4, 4.9, 5.4, 5.9 and 6.4 m.

## TECHNOLOGY TRANSFER

An essential component of our research activities is the transfer of knowledge to operational sectors of Inland Waters Directorate and to the rest of the Department. In the past year input was provided to: negotiations for Qu'Appelle Implementation; the Canada-Manitoba Mercury Agreement; Parks Canada both the water quality program definition in Nahanni National Park and in regards to Implications of the Slave River hydro proposal; the Environmental Protection Service for program definition and scientific guidance of their Scientific Programs Branch; the Regional Director General's office on issues of water concerns and water resource management and research; Water Quality Branch Headquarters in developing effects monitoring policy and programs; Manitoba Environment for mercury and heavy metal monitoring strategies in the Red River and elsewhere; and to all sectors of Inland Waters Directorate within Western and Northern Region. Other technology transfer activities included nine formal lectures and seminars that were delivered by invitation to government and external groups within the region and throughout Canada.

In 1983 a workshop on Prairie Lake Restoration and Manipulation was hosted for the purpose of developing a research strategy to meet client needs for surface water rehabilitation in the southern prairies. Workshop participants who came from as far afield as the United Kingdom, Switzerland and France represented a broad spectrum of disciplines and practical experience with lake restoration.

## STAFF LIST

### Chief — Dr. E.D. Ongley

#### Researchers

Dr. T.A. Jackson	metal biogeochemistry, nutrient geochemistry
Dr. B.C. Kenney	mixed layer dynamics, nutrient dynamics, physical limnology
Dr. E.D. Ongley	fluvial geomorphology, sedimentology
Dr. W.F. Warwick	paleolimnology, benthic biology

#### Technical Staff

Ms. C. Casey  
Mr. J.C. Mollison  
Mr. K. Supeene  
Mr. J.P. Tisdale

## COMMITTEE MEMBERSHIP

### E.D. Ongley

IWD Regional Management Committee

Executive Committee, International Association for Sediment Water Science — Treasurer

Technical Advisory Committee,  
Canada-Manitoba Mercury Agreement

Regional Pesticides Committee

## PUBLICATIONS

*Jackson, T.A.* 1983. Effects of Inorganic Cadmium, Zinc, Copper and Mercury on Methyl Mercury Production in Lake Sediments — Evidence for Selective Inhibition and Stimulation of Microbial Species Based on Variation in Heavy-metal Tolerance. IN: J.O. Nriagu (ed.), *Environmental Impacts of Smelters*, John Wiley & Sons, N.Y. (In press).

*Jackson, T.A.* 1983. Mercury in the Qu'Appelle River System of Saskatchewan and its Lakes and Tributaries. Unpublished report, Qu'Appelle Implementation Office (contract no. 21).

*Jackson, T.A.*, J.W. Parks, P.D. Jones, R.N. Woychuk, J.A. Sutton and J.D. Hollinger 1982. Dissolved and Suspended Mercury Species in the Wabigoon River (Ontario, Canada): Seasonal and Regional Variations. *Hydrobiol.*, 92: 473-487.

*Kenney, B.C.* 1982. Beware of Spurious Self-correlations! *Water Resour. Res.*, 18: 1041-1048.

*Kenney, B.C.* 1983. Dynamics of Phosphorus in Lake Systems. *Can. J. Fish. Aquat. Sci.* (In press).

*Kenney, B.C.* 1983. Dynamics of Phosphorus in a Chain of Lakes: the Fishing Lakes. Unpublished report, 46 pp.

*Warwick, W.F.* 1983. The Palaeolimnology of Pasqua Lake, Southeastern Saskatchewan: the Chronology of Sediment Deposition. Report to the Qu'Appelle Implementation Board, 56 pp.



## TECHNICAL OPERATIONS DIVISION

The Technical Operations Division provides a wide variety of technical support to the field research studies of NWRI, its regions and, where possible, to other departments, agencies and universities.

Areas of responsibility include field measurement, sample collection and some basic analyses of physical, chemical and biological parameters and sediment from freshwater systems aboard major research ships, launches, shore-based field parties and diving operations. The Division is also responsible for the preparation, modification, field use and maintenance of a wide variety of mechanical, electronic and hydraulic sampling and data acquisition systems.

The Division arranges for the acquisition and scheduling of major research ships, launches and land sites; the coordination of all NWRI field research studies to ensure effective and efficient use of technical staff, vehicles and equipment. The Division also ensures a high level of safety for all field operations.

During 1983/84, TOD maintained 10 studies in support of NWRI and outside research requirements. The division also provided direct technical support to 76 NWRI studies.

### SHIP SURVEY SECTION

All data gathering on the Great Lakes is done on measurement platforms from research vessels by the Ship Survey Section — a major contribution being water quality and eutrophication parameters which form the data base input to the Water Quality Board Annual Report to the International Joint Commission.

**CSS ADVENT.** Twelve lower Great Lakes cruises were completed by CCS ADVENT in support of NWRI studies. In Lake Ontario, 3 Sediment Trap Mooring cruises were conducted to 1) measure sedimentation and regeneration rates of nutrients and contaminants; 2) relate phytoplankton response to loading changes and the effect of eutrophication on contaminant management. The Niagara River Survey was conducted to determine the seasonal characteristics of the river plume in support of toxic contaminants and other related biochemical studies.

In Lake Erie, the ADVENT conducted 5 Surveillance Continuity cruises to establish and standardize an annual survey program and to provide historical data suitable for the detection of important emerging pattern changes. A two-week cruise supported Chemical Forms and Potential Availability of Trace Metals — its purpose to study contaminants, including toxic metal ions, arising from sources in the Detroit River watershed and their impact on Lake Erie. The ADVENT was utilized to collect sediment samples from the Upper Niagara River for determination of practical size and composition effect on concentration of selected contaminants in sediment samples. The ADVENT was also utilized to refurbish a sediment trap mooring in Lake Erie initially installed by CSS LIMNOS.

**CSS BAYFIELD.** The majority of work conducted by CSS BAYFIELD was in support of three Great Lakes Fisheries Research Branch programs. The Long Term Bioindex Monitoring Program was continued to collect chemical and biological data simultaneously at selected stations on Lake Ontario on a weekly basis. A total of 32 such cruises were carried out during the field season. Other work carried out by BAYFIELD included benthos sampling and

thermal bar studies between the Genesee River and Pt. Weller. Picoplankton and in situ toxicity studies were carried out to assess the effects of stress from sediment-associated toxic substances on algal metabolism, especially picoplankton and ultraplankton. On nearly fifty percent of the cruises, additional piggyback work was coordinated and conducted. Many water and sediment samples were taken as well as deployment and recovery of satellite-tracked drogues.

**CSS LIMNOS.** Thirty-six cruises were completed by the major research vessel, CSS LIMNOS on Lakes Ontario, Erie, Huron and Superior. Detailed plans and reports were prepared for each cruise and are available from Technical Operations Division upon request (Fig. 1). A detailed overview of CSS LIMNOS activities can be found in the TOD Activity Summary '83/84. The multi-disciplinary cruises consisted of:

#### Lake Ontario

- 5 — Sediment Trap Mooring
- 3 — Open Lake Surveillance
- 3 — Contaminants — Plankton Dynamics
- 3 — Current Meter Mooring
- 2 — Aquatic Invertebrates Collection
- 2 — Chemical Forms and Potential Availability of Trace Metals
- 1 — Water Quality Branch Field Trials

#### Lake Erie

- 3 — Contaminants — Plankton Dynamics
- 2 — Sediment and Phosphorus
- 1 — Sediment Bank Study
- 1 — Surveillance Continuity Study

#### Lake Huron

- 3 — Contaminants — Plankton Dynamics
- 1 — Sediment Bank Study

#### Lake Superior

- 4 — Open Lake Surveillance
- 1 — Sediment Bank (Fig. 2)
- 1 — Productivity and Phosphorus Limitation

### FIELD SURVEY SECTION

The Field Surveys Section coordinates and provides logistics, equipment and personnel resources in support of NWRI field research studies. The Section's four organizational units directly supported many shore and launch-based studies as well as provided technical services to other support sections at NWRI. Launches, small boats, land sites, sampling equipment, laboratory trailers and vehicles were acquired and scheduled for use. Staff were assigned to a wide variety of survey tasks and geographic locations.

**Rigging Unit.** The rigging staff, shop, outdoor compounds and highbay warehouse facilities provided direct and indirect support to most NWRI field activities.

Services were provided at dockside to support loading and off-loading ships. Buoys, hardware, winches, generators, mooring arrays and other equipment was prepared for the field; forklift, heavy-truck driving and trailer towing services were provided. Field support for samples and equipment transport ranged from Sault Ste. Marie, Ontario

	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
JANUARY							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
FEBRUARY	30	31	1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	1	2	3	4	5
MARCH	6	7	8	9	10	11	12
	13	14 Lake	15 Ontario	16 Surveillance	17 Lake	18 Ontario	19 CCIW
	20 CCIW	21 CCIW	22 Trace Metals	23 Lake	24 Ontario	25 Moorings	26 Lake Ontario
	27 CCIW	28 Trace Metals	29 CCIW	30 Trace Metals	31 CCIW	1 CCIW	2 CCIW
	3 CCIW	4 CCIW	5 Lake	6 Ontario	7 Surveillance	8 Lake Ontario	9 CCIW
APRIL	10 CCIW	11 Lake Ontario	12 Sediment	13 Trap	14 CCIW	15 CCIW	16 CCIW
	17 CCIW	18 CCIW	19 CCIW	20 CCIW	21 CCIW	22 CCIW	23 CCIW
	24 CCIW	25 W.Q. Trials	26 CCIW	27 CCIW	28 CCIW	29 CCIW	30 CCIW
	1 CCIW	2 Lake	3 Ontario	4 Aquatic	5 Invertebrates	6 CCIW	7 CCIW
	8 CCIW	9 Lake Ontario	10 Sediment	11 Trap	12 CCIW	13 CCIW	14 CCIW
MAY	15 CCIW	16 Upper	17 Lakes	18 Surveillance	19 Upper	20 Lakes	21 Surveillance
	22 Upper	23 Lakes	24 Surveillance	25 Upper	26 Lakes	27 Surveillance	28 Upper
	29 Lakes	30 Surveillance	31 Lake	1 Erie	2 Sediment	3 and	4 Phosphorus
	5 Resuspension	6 Lake Erie	7 Sediment	8 Trap	9 Moorings	10 CCIW	11 CCIW
	12 CCIW	13 CCIW	14 CCIW	15 CCIW	16 CCIW	17 CCIW	18 CCIW
JUNE	19 CCIW	20 Lake	21 Superior	22 Surveillance	23 Lake	24 Superior	25 Surveillance
	26 Lake Superior	27 Surveillance	28 Lake Superior	29 Surveillance	30 Lake	1 Superior	2 Surveillance
	3 Sault Ste Marie	4 Sault Ste Marie	5 Lake	6 Superior	7 Productivity	8 and	9 Phosphorus
	10 Limitation	11 Sault Ste Marie	12 Lake	13 Superior	14 Sediment	15 Bank	16 Study
	17 Lake	18 Superior	19 Sediment	20 Bank	21 Study	22 Lake	23 Superior
JULY	24 Sediment	25 Bank	26 Lake	27 Superior	28 CCIW	29 CCIW	30 CCIW
	31 CCIW	1 CCIW	2 CCIW	3 CCIW	4 CCIW	5 CCIW	6 CCIW
	7 CCIW	8 Lake Ontario	9 Sediment Trap	10 Moorings	11 CCIW	12 CCIW	13 CCIW
	14 CCIW	15 Lake	16 Erie	17 Sediment	18 and	19 Phosphorus	20 Resuspension
	21 CCIW	22 Lake	23 Ontario	24 Trace	25 Metals	26 CCIW	27 CCIW
AUGUST	28 CCIW	29 Lake	30 Superior	31 Surveillance	1 Lake	2 Superior	3 Surveillance
	4 Lake Superior	5 Surveillance	6 Lake Superior	7 Surveillance	8 Lake	9 Superior	10 Surveillance
	11 Lake	12 Huron	13 Lake Erie	14 Surveillance	15 Continuity	16 CCIW	17 CCIW
	18 CCIW	19 Lake Ontario	20 Aquatic	21 Invertebrates	22 CCIW	23 CCIW	24 CCIW
	25 CCIW	26 CCIW	27 Lake Ontario	28 Moorings	29 Lake	30 Ontario	1 CCIW
SEPTEMBER	2 CCIW	3 Lake	4 Ontario	5 Surveillance	6 Lake Ontario	7 CCIW	8 CCIW
	9 CCIW	10 CCIW	11 Lake	12 Superior	13 Surveillance	14 Lake	15 Superior
	16 Surveillance	17 Lake	18 Superior	19 Surveillance	20 Lake	21 Superior	22 Surveillance
	23 Lake Superior	24 Surveillance	25 Lake	26 Superior	27 Surveillance	28 CCIW	29 CCIW
	30 CCIW	31 CCIW	1 CCIW	2 Lake Ontario Moorings	3 CCIW	4 CCIW	5 CCIW
OCTOBER	6 CCIW	7 Lake	8 Ontario	9 Sediment Trap	10 Moorings	11 CCIW	12 CCIW
	13 CCIW	14 CCIW	15 CCIW	16 CCIW	17 CCIW	18 CCIW	19 CCIW
	20 CCIW	21 CCIW	22 CCIW	23 CCIW	24 CCIW	25 CCIW	26 CCIW
	27 CCIW	28 CCIW	29 CCIW	30 CCIW	1 CCIW	2 CCIW	3 CCIW
	4 CCIW	5 Whitby	6 Dry	7 Dock	8 Whitby	9 Dry	10 Dock
NOVEMBER	11 Whitby	12 Dry	13 Dock	14 Whitby	15 CCIW	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	31
DECEMBER							

Figure 1

CSS LIMNOS 1983



**Figure 3**  
Liming of Frisken Lake, B.C. in support of study AED 437.



**Figure 5**  
The final bluff survey, Port Burwell, study HD 345.

**Figure 6**  
Snow coring at the Turkey Lakes watershed, Sault Ste. Marie.





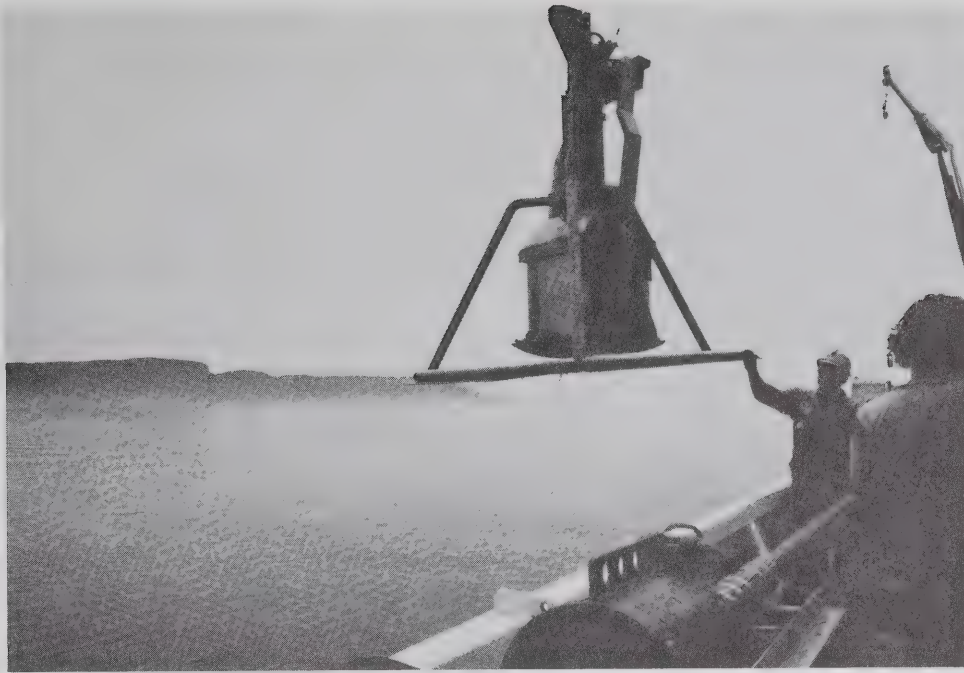


Figure 2 Box coring from CSS Limnos on Lake Superior near Thunder Bay.

to Pt. Sapin, New Brunswick. Another major responsibility has been the maintenance of the NWRI vehicle fleet.

**Field Stores Unit.** This Unit maintained, issued and received a store of field sampling and support equipment. The inventory of over 500 line items was in constant use by field staff of NWRI. The scheduling and issue of 5 vehicles for local use by NWRI staff was also provided.

**Underwater Operations Unit.** Responsibility was maintained for the safe conduct of all diving operations undertaken by DOE and DFO staff at CCIW. The Unit holds a responsible position with the Departmental Committee for Diving Safety which determines and enforces diving safety policy. The Unit utilized a large inventory of specialized research diving equipment. Dive support was given to a number of NWRI field studies during 83/84.

**Shore and Launch Operations Unit.** Support was provided to 62 NWRI studies as well as 55 minor additional requests during the year. All services provided were in support of approved NWRI activities and detailed reports are available. A few of the major field studies are listed:

- No. 432 — Elmira Streams for sources and fate of ammonia-nitrogen in highly eutrophic or heavily polluted streams
- No. 223 — Elmira Streams to determine pathways and accumulation rates of organic contaminants in fish
- No. 411 — Algonquin Park sediment traps for metals related studies
- No. 437 — South Central British Columbia to evaluate carbonate-phosphate chemistry of interior lakes (Fig. 3)
- No. 109 — Eastern Lake Ontario for fish habitat studies (Fig. 4)

- No. 345 — Pt. Burwell final bluff erosion topographic survey (Fig. 5)
- No. 803 — Lake Superior for Canadian Wildlife Service re effects of toxics on Herring Gull colonies
- No. 806 — Georgian Bay for GLFRB conducting LRTAP and primary production experiments
- No. 236 — Shubenacadie River, Nova Scotia for toxic metals studies
- No. 231 — Full-time staff at Sault Ste. Marie Turkey Lakes Watershed in support of LRTAP studies (Fig. 6 & 7)
- No. 625 — Sudbury Lakes LRTAP sampling
- No. 224 — Lake Superior Toxaphene Study
- No. 314 — Moose River Ice Jamming studies
- No. 216 — Niagara River surface microlayer sampling

## LIMNOLOGICAL INSTRUMENTATION SECTION

Instrumentation support services at NWRI keep increasing with emphasis on new and varied types of equipment. The staff have kept abreast of state-of-the-art systems to provide the necessary support. During the year, the staff were busy upgrading, retrofitting or modifying existing equipment for optimum field performance. Seven major modifications to equipment were performed as follows:

1. Two new EBT's were manufactured and are awaiting temperature sensors.
2. The rack-mounted acoustic release deck unit was converted to portable use and fitted with rechargeable batteries.
3. A new and improved alkaline battery was designed and tested, and is in use in all Geodyne current meters and digitizers, with excellent results.



Figure 4 Under ice diving in eastern Lake Ontario in support of habitat studies DO 109.





**Figure 7 Little Turkey Lake 40 miles north of Sault Ste. Marie.**

4. A new, improved and cheaper cassette was tested. After a few modifications, it is working well and is the standard cassette used in all Geodyne current meters and digitizers.
5. A new battery is in the design stage for the acoustic release units. If it proves successful, a significant cost saving will result.
6. An existing portable EBT system was integrated to a transmissometer sensor to form a portable EBT/transmissometer system. The system has been in use at the P&Y Region and field reports are very encouraging.
7. Year-round operation of meteorological and solar radiation sites has been upgraded for winterized operation.

## **STAFF LIST**

**Chief — Mr. H.B. Macdonald**  
**Secretary — Mrs. S.R. Mitchell**  
**Administrative Officer — Mrs. C. Kennedy**

**Ship Survey Section**  
 Head, Mr. P.M. Healey

### **Sr. Technical Staff**

Mr. B.H. Moore	OIC CSS LIMNOS, Nova Scotia
Mr. S.B. Smith	OIC CSS ADVENT/CSS BAYFIELD, science cruises
	CSS LIMNOS, Niagara-on-the-Lake, Yukon
Mr. P.R. Youakim	OIC CSS BAYFIELD
Mr. E.H. Walker	surveillance, CWS, Algonquin, Moose River

### **Technical Staff**

Mr. J.A. Kraft	surveillance, science cruises, field projects
Mr. K.J. Hill	surveillance, diving, Pt. Burwell
Mr. G.G. LaHaie	OIC CSS ADVENT, surveillance, science cruises
Mr. R.J. Hess	OIC CSS ADVENT, IWD

### **Students**

Mr. G.W. Stobbe	CSS LIMNOS
Mr. J.P. Haynes	CSS LIMNOS

**Secondment from Water Survey of Canada, Guelph**  
 Mr. A.C. Kular surveillance, science cruises

### **Field Surveys Section**

Head, Mr. W.B. Taylor  
 Sr. Field Officer, Mr. M.R. Mawhinney

### **Sr. Technical Staff**

Mr. T.J. Carew	LRTAP — Sault Ste. Marie
Mr. L.E. Benner	CWS, surveillance
Mr. G.J. Koteles	Yukon, Algonquin, science cruises

### **Students**

Ms. M.L. Walli	surveillance, shore projects
Ms. K. Gracey	shore projects
Mr. A.K. Sztas	rigging shop, Turkey Lakes

### **Contract**

Mr. K. Weber	shore projects, LIS
--------------	---------------------

### **Rigging Unit**

Head, Mr. L.J. Lomas	foreman rigger, Nova Scotia
----------------------	-----------------------------



**Support Staff**

Mr. H.E. Greencorn

Mr. G.M. Perigo

rigger, Nova Scotia

vehicle maintenance, Nova  
Scotia

**Underwater Operations Unit**

Head, Mr. F.H. Don

**Support Staff**

Mr. G.D. Bruce

diving, OIC GLFRB Owen

Sound, Turkey Lakes runoff

Mr. J.E. Tozer

diving, Turkey Lakes runoff,  
surveillance, field projects

Ms. C. Bisutti

diving, science cruises,  
surveillance, paleolimnology

**Field Stores Unit**

Mr. W.D. Hunt

**Limnological Instrumentation Section**

Head, Mr. J.A. Diaz

**Student**

Mr. G.L. Voros

LIS, rigging shop

**Current Meters and Data Abstraction Unit**

Head, Mr. J.A. Tyler

**Field Instruments and MET Systems Unit**

Head, Mr. E.G. Smith

## STAFF SERVICES DIVISION

Staff Services Division (SSD) is the lead agency for the provision of administrative, financial, property management, material management and records management services to all Environmental Conservation Service (ECS) elements, as well as to those of the Environmental Protection Service, located at the Canada Centre for Inland Waters (CCIW). In addition, common support services are provided to those agencies of the Department of Fisheries and Oceans (DFO) located at CCIW as well as to the Department of Supply and Services and the Ontario Area Personnel Office, Department of the Environment (DOE).

### ADMINISTRATION SECTION

This Section is responsible for providing administrative and financial support to all NWRI Divisions. Additionally, it provides Institute-wide functions such as compiling the NWRI Conference Travel Plan, writing new and updating existing Institute Administrative Procedures, providing liaison and coordination of personnel-related activities with the Ontario Area Personnel Office, DOE, information services, the coordination of student hiring programs, the Canada Savings Bonds Drive and the United Way Campaign, the preparation and analysis of monthly reports on the utilization of Institute's person-year resources, and expertise in all matters concerning safety, fire and security.

This year Office Automation was introduced, servicing NWRI Divisions as well as the Inland Waters Directorate-Ontario Region and the National Water Quality Laboratory. The coordination of the project rests with a staff member of this Section. The first phase of this project is a familiarization with the equipment and its capabilities for project automation as well as word processing. A study was undertaken to identify the needs for office automation within the Institute and a strategy developed for implementing automation over the longer time frame.

A newly-constituted CCIW Safety Committee has been introduced with expanded terms of reference to ensure greater participation by Senior Management and the Unions. It is intended that this Committee be more involved and pro-active in all matters concerning safety. Regular safety inspections have been conducted with effective follow-up taking place. Fire drills have been held to test the Institute's emergency organization. St. John Ambulance first-aid courses and on-site fire-fighting equipment training and CPR training courses were held for staff.

A Contracts Review Committee has been formed to ensure that all NWRI Contracts for Services and Materiel comply with Governmental and Departmental Contracts Directives.

The Information Unit of this Section provides answers to queries received from Provincial and Municipal authorities, other Federal Government Departments, academics and scientists, as well as from the general public. Information is provided informally, or in accordance with Access to Information legislation. Requests for speakers on specific subjects by service clubs, professional groups, universities and colleges are accommodated on an individual basis, and tours of the Centre are coordinated.

The Administration Section also provides management consultation for the DOE Equal Opportunities for Women Committee.

### BUILDING AND PROPERTY SERVICES SECTION

This Section is responsible for the physical operation and maintenance of the buildings, intrinsic equipment and the grounds, roadways and parking lots within the confines of the complex. It also provides technical assistance and advice concerning alterations, modifications or equipment installation for all onsite agencies. Finally, it is responsible for the 55-line PBX servicing over 600 telephones, data and other communications systems throughout the complex.

Major projects this year included: (1) the completion of the CCIW Laboratory Space Reallocation Project undertaken in order to house the new National Water Quality Laboratory; (2) the installation of the Emergency Voice Alarm System to service all agencies at CCIW; and (3) the commencement of the first phase in making CCIW barrier-free to the Handicapped.

### MATERIEL MANAGEMENT SECTION

This Section is responsible for providing, on a day-to-day basis, procurement, inventory control and assets management, disposal, warehousing and stores and shipping/receiving services to all ECS agencies located at the CCIW. Highlights of this year's work include: (1) a complete update of the computerized Capital Assets Inventory, including the location of major items; and (2) completion of a wall-to-wall inventory, including furniture.

### FINANCE SECTION

The Finance Section provides centralized computer accounting services for all ECS units at CCIW (NWRI, Inland Waters Directorate-Ontario Region, Lands Directorate-Ontario Region and the Water Quality Laboratory). It also provides the accounting function for funds provided by the Regional Director General-Ontario Region for the Great Lakes Water Quality Agreement. In addition, the Section is responsible for providing liaison between other government departments (federal, provincial and municipal) and suppliers with regard to payment of accounts and contracts.

### LIBRARY SECTION

This Section provides library services and facilities to all agencies located at the CCIW in support of their research and survey programs. Highlights for the period covering this report include: (1) the installation of a security system which has been found to be most effective in reducing losses of books and journals; and (2) the finalization of a Disaster Plan to safeguard the collection in the event of fire, flood, etc. Also, Disaster Teams made up of CCIW staff have been established to respond to any and all emergencies on an around-the-clock basis.

### CENTRAL REGISTRY SECTION

Central Registry provides mail services to all in-house occupants as well as registry facilities for NWRI and Inland Waters Directorate-Ontario Region. Telex, telecopier and photocopying services are provided for the Centre.

## **STAFF LIST**

**Chief — Mr. J.D. Smith**  
**Secretary — Mrs. H. Zrostek**

**Financial Services**  
Head, Mr. A.B. Mitchell

**Support Staff**  
Mrs. B. Titley  
Mrs. Y. Hutton  
Mr. D. Jefferson  
Mr. R. Haswell  
Mrs. E. Wendel

**Central Registry**  
Supervisor, Mrs. E. Rae

**Support Staff**  
Mrs. M.T. Solvason  
Mrs. J.A. Sims  
Mr. D. Foran

**Materiel Management**  
Head, Mr. D.A. Burton

**Support Staff**  
Mr. J.P. Mellon  
Mr. S.E. Hicks  
Mrs. M. Eadie  
Mr. W. Coventry  
Ms. M. Ross

**Building and Property Services**  
Head, Mr. D.F. Stewart

Safety Officer, Mr. R.J. Gray Nurse, R. Calcott

**Support Staff**  
Mr. J.C. Stewart  
Mr. D.J. Smit  
Mr. C.K. Platt  
Mr. K. Taylor  
Mr. F. Adams  
Mr. A.K. Allaby  
Mr. D.W. Clewley  
Mr. J.P. Denomme  
Mr. W.A. Johnson  
Mr. T. Comiskey  
Mr. R.J. McCurdy  
Mr. W. Murphy  
Mr. M.S. Wyne  
Mr. G.R. Johnstone

**Library Services**  
Head, Ms. E. Dowie

**Support Staff**  
Ms. P. Haley  
Mrs. J. Tinney  
Mrs. K. Finch  
Ms. P. Bennett

**Information Unit**  
Officer, Vacant

**Canada Centre for Inland Waters**





Canada

CAI  
MT64

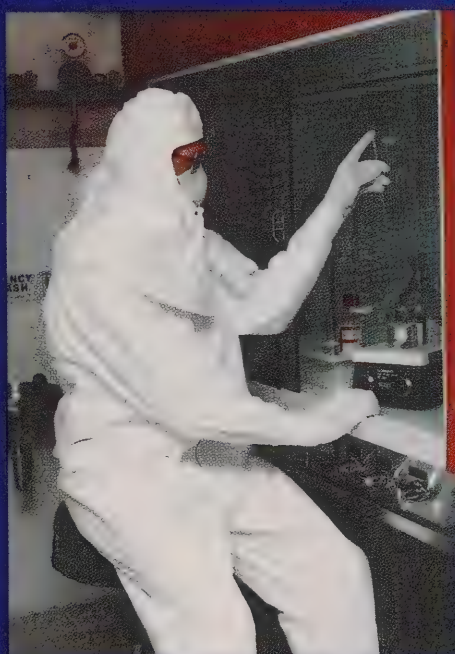
Environment  
Canada

Environnement  
Canada

Government  
Publications

# National Water Research Institute

1985-1986  
Annual Report





---

**Editor:** J. Lawrence

**Production Team:** J. Andrews  
J. Burford  
W.D. Finn  
P.C. McColl  
S. Ponton

Cover design by P.C. McColl  
Publication disponible en français sur demande

# **NATIONAL WATER RESEARCH INSTITUTE**

**1985-1986  
Annual Report**

National Water Research Institute  
Inland Waters Directorate  
P.O. Box 5050  
Burlington, Ontario  
Canada  
L7R 4A6

## NATIONAL WATER RESEARCH INSTITUTE

### NOTE

NOTICE is hereby given that mention of any product or material in this publication is not to be taken as indicating that the National Water Research Institute in any way approves, recommends or endorses any such product or material. No mention shall be made of the National Water Research Institute or of this publication in any advertising, sales promotion, reports or other written or graphic material which would indicate or imply that the National Water Research Institute approves, recommends or endorses any product or material mentioned herein, or which has as its purpose an intent to use the name of the National Water Research Institute or this publication as a means, directly or indirectly, of causing, aiding or enhancing the sale or use of any such advertised product or material.

Published by authority of  
the Minister of the Environment



# CONTENTS

	Page
<b>FOREWORD</b> .....	1
<b>NWRI ORGANIZATION CHART</b> .....	2
<b>EXECUTIVE SUMMARY</b> .....	3
<b>DIRECTOR'S OFFICE</b> .....	8
Senior Scientist .....	8
Science liaison and coordination .....	8
Senior Research Management Advisor .....	8
WHO Collaborating Centre on Surface and Ground Water Quality .....	8
Fish habitat studies .....	9
Special project: St. Clair River pollution investigation .....	9
Staff list .....	10
Committee membership .....	10
Publications .....	10
<b>AQUATIC ECOLOGY DIVISION</b> .....	11
Ecological Impact Section .....	11
Great Lakes Rehabilitation Section .....	13
Nutrient Pathways Section .....	15
Staff list .....	17
Committee membership .....	17
Publications .....	18
<b>AQUATIC PHYSICS AND SYSTEMS DIVISION</b> .....	20
Physical Limnology Section .....	20
Environmental Simulation Section .....	20
Environmental Optics Section .....	24
Data Management Section .....	24
Staff list .....	25
Committee membership .....	26
Publications .....	26
<b>ENVIRONMENTAL CONTAMINANTS DIVISION</b> .....	29
Organics-Pathways Section .....	29
Organics-Properties Section .....	31
Inorganics Section .....	33
Radionuclides Section .....	34
Acid Deposition Section .....	35
Staff list .....	36
Committee membership .....	37
Publications .....	37

<b>ANALYTICAL METHODS DIVISION</b> .....	40
Analytical Chemistry Research Section .....	40
Quality Assurance and Methods Section .....	43
Microbiology Laboratories Section .....	43
Computer Services Section .....	46
Staff list .....	46
Committee membership .....	47
Publications .....	48
<b>HYDRAULICS DIVISION</b> .....	50
Environmental Hydraulics Section .....	50
Shore Processes Section .....	55
Technical Services Section .....	57
Engineering Services Section .....	58
Manufacturing and Technical Development Section .....	59
Drafting Services Section .....	60
Office Services Section .....	60
Staff list .....	60
Committee membership .....	61
Publications .....	62
<b>NWRI PACIFIC AND YUKON REGION</b> .....	65
Staff list .....	68
Committee membership .....	68
Publications .....	68
<b>NWRI WESTERN AND NORTHERN REGION</b> .....	70
Staff list .....	75
Publications .....	75
<b>TECHNICAL OPERATIONS DIVISION</b> .....	76
Ship Survey Section .....	76
Field Surveys Section .....	79
Limnological Instrumentation Section .....	80
Staff list .....	80
<b>STAFF SERVICES DIVISION</b> .....	81
Administration Section .....	81
Building and Property Services Section .....	81
Materiel Management Section .....	81
Finance Section .....	81
Library Section .....	82
Central Registry Section .....	82
Staff list .....	82



*Your file    Votre référence*

*Our file    Notre référence*

It is with pleasure that I introduce this summary of the research accomplishments of the National Water Research Institute, Inland Waters Directorate, Environment Canada, for 1985 and 1986. The results reported here address a variety of issues of national significance associated with the protection, enhancement or sustainable development of fresh water in Canada.

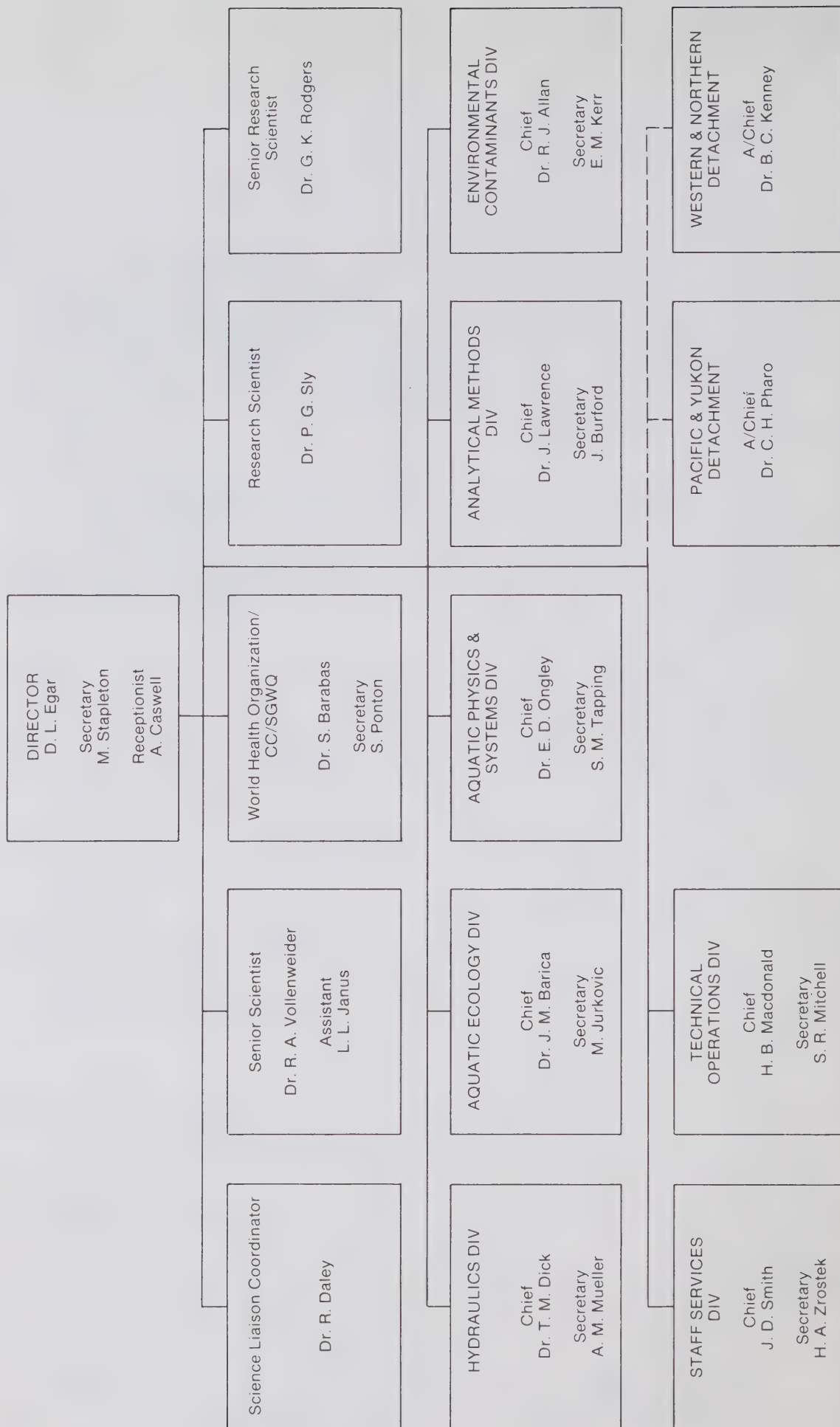
In this edition, the staff report on recent progress in a variety of important areas, including the fate and effects of environmental toxicants, long range transport of air pollution, eutrophication and lake rehabilitation, river flooding and ice jams, predictive modelling and analytical methods development. The research encompasses the full range of scientific disciplines within lake and river limnology.

The Institute is dedicated to scientific excellence and social responsibility. These results represent the efforts of the Institute's talented staff to advance and communicate new knowledge of scientific merit and practical importance. It is my hope and expectation that this knowledge will be of value in the ongoing management of Canada's inland water resources.

D.L. Egar  
Director



# ORGANIZATION CHART NATIONAL WATER RESEARCH INSTITUTE



## EXECUTIVE SUMMARY

The research accomplishments of the National Water Research Institute (NWRI), Inland Waters Directorate, Environment Canada, for the fiscal years 1984/85 and 1985/86 are summarized. The Institute, located at the Canada Centre for Inland Waters in Burlington, Ontario, undertakes original research on freshwater issues of national significance to Canada. The knowledge and expertise derived from its research are communicated to Environment Canada, the Canadian water management community and the general public for use in resolving aquatic environmental problems.

Historically, research at NWRI has been conducted by five research divisions, each with a particular disciplinary or functional role (contaminants, hydraulics, ecology, lake physics, analytical methods). To enhance the integration and flexibility of the Institute's research programs and to maintain economy and efficiency in a time of restraint, a comprehensive Project Management System was implemented in late 1985. Research activities were organized into a series of multidisciplinary projects, each addressing an issue of scientific and managerial importance. Projects will be the focus for planning and managing future research, for developing internationally recognized expertise and for communicating results and their implications to users. The divisional organization was retained to ensure disciplinary cohesion and administrative stability.

A summary follows of the research and communication highlights of major, "flagship" projects during the review period. New projects, or groupings of projects, which have been implemented for 1986/87 are also briefly summarized. Together, they comprise the core research program that NWRI will undertake over the next several years.

Research results from the Western and Northern and Pacific and Yukon regional detachments of NWRI are included here for the last time. Effective April 1986, these two groups were reorganized as the Limnology Division of the National Hydrology Research Institute, Saskatoon.

**Fate and Effects of Toxic Contaminants.** To develop control strategies and predictive capabilities for management purposes, the properties, pathways, fate and biotoxic effects of toxic chemicals are being systematically characterized through ongoing laboratory and field experiments. Highlights from the review period include the following:

- Research on the fate of chlorophenols in the North Saskatchewan River was undertaken. Anaerobic dehalogenation was shown to be a critical pathway for chlorophenol degradation in this and other systems.
- The rate of mercury methylation in sediments of the Qu'Appelle Basin of Saskatchewan was shown experimentally to be controlled, not by the availability of inorganic mercury, but primarily by trophic conditions.
- Studies of factors affecting methylation, demethylation and bioaccumulation of mercury by fish in northern Manitoba showed that elevated mercury levels are to be expected following flooding by northern hydroelectric reservoirs.
- Toxicity tests using Microtox and octanol-water partition coefficients were found to parallel each other for a wide range of organic chemicals, including chlorophenols, anilines, benzenes, nitrobenzenes and pyridines.
- A study to evaluate organic and inorganic contaminant pathways in the Mackenzie River was initiated in response to native concerns and recognized water data deficiencies. Water, suspended and bottom sediments and biological samples were collected under summer flow conditions.
- Deformities in *Chironomus* larvae are being developed as *in situ* bioindicators to assess the ecological impact of contaminants in the Saskatchewan River Basin.
- Formation of organic coatings by colloidal fibrils in lake water was investigated. These fibrils are important for metal speciation changes in lake water.
- The effects of specific heavy metals on the metabolic activities of natural bacterial populations were evaluated, using populations from Hamilton Harbour.

**Contaminated Sediments.** To aid the development of site rehabilitation guidelines, the availability, biogeochemical pathways and effects of sediment contaminants from the Great Lakes and smaller systems are being determined. Long-term contaminant release from bottom sediments, which can slow recovery following point-source control, will also be quantified. Highlights include the following:

- Bioconcentration factors for chlorinated hydrocarbons by aquatic worms varied with chemical structure and sediment type. The worms selectively accumulate chemicals from the sediments in which they live; this has important implications for fish predators.
- Historical changes in the accumulation of pollutant metals since 1910 were determined using  $^{210}\text{Pb}$  dating of lake sediments. Metal deposition rates in lakes from Nova Scotia, eastern Ontario and upper New York State were comparable.
- Discontinuities were found in the vertical distribution of suspended sediments in Lake Manitoba. The results have important implications for redistribution of sediment contaminants in large, shallow lakes.



**Upper Great Lakes Connecting Channels Study.** This ongoing project is developing the knowledge and expertise needed to assess the magnitude of toxic contamination of the upper Great Lakes connecting channels while protecting Canadian interests in support of remedial action. Contaminant and nutrient sources are being identified and quantified, biological toxicity is being assessed, and models to predict contaminant distribution will be developed. Highlights from the past two years include the following:

- A multidisciplinary NWRI team collaborated with the Ontario Ministry of the Environment in an emergency study to determine the nature, chemical composition and specific source of contaminant "puddles" discovered on the St. Clair River bottom near Sarnia, Ontario. The identity and source of the puddles, other contaminant sources along the river and the extent of contaminant transport across the border were determined. As a result, Dow Chemical removed the sediment puddles, eliminated the plant source and developed procedures to minimize future seepage to the river.
- A special issue of the *Journal of Great Lakes Research* dealing with pollution of the St. Clair River, Lake St. Clair and the Detroit River was published; 10 of the 23 publications were authored by NWRI staff. Many toxic chemicals, such as HCB, HCB and OCS, were identified in the papers. Sources were suggested and pathways of movement, both spatially and into food webs, were resolved. The sources, pathways, fate and effects of tributyltins, alkylleads, many persistent and bioaccumulated organochlorines and volatile organics were also described.

**St. Lawrence River Rehabilitation.** The degree of hazard posed to aquatic biota and humans from toxic contaminants in the St. Lawrence River (and upper estuary) is unknown and the expertise needed for restoration planning has not been developed. Research is undertaken to determine the magnitude, distribution, loadings, principal pathways, fate and biological effects of toxics in the river, as well as the ecological impacts of contaminants at the mouth of the estuary. Highlights from the early phase of work include the following:

- An initial cruise from Lake Ontario to Quebec city was made to collect sediment and water samples for a preliminary assessment of contaminant types, distribution and fate.
- The surface sediments of Lake St. Louis were surveyed and maps showing the extent and size-distribution of the sediments prepared.
- An intensive microbiological study of Lake St. Louis for toxicants and bacterial biomass distributions was undertaken. Over 80% of surface sediments were found to contain toxicants, as determined by the Microtox test.

**Long Range Transport of Air Pollutants.** To improve the information base, expertise and scientific credibility for effective national and international management of LRTAP, a major research effort, in progress, is quantifying the biogeochemical processes which control the response of lakes and rivers to the deposition of acids and other contaminants in eastern Canada. Improved expertise in the design, conduct and interpretation of acid rain monitoring programs is also being developed. Highlights include the following:

- Sulphur stored in the sediments of the Turkey Lakes was determined, by stable isotope techniques, to occur in the reduced form, mostly as organosulphur compounds. Reduction of pollutant sulphur was shown to be the most important process for the generation of buffering alkalinity.
- Low pH stress on natural lake bacteria adversely affects their cellular surface structure, metabolic rates and ability to decompose organic matter.
- Waters in the Atlantic Provinces were shown to be the most sensitive in eastern Canada to acid rain.
- During spring, short-term acidification of surface waters was shown to be strongly influenced by rainfall. In addition, nitrate deposition was found to be as important as sulphate deposition in influencing acidity during snowmelt.
- Several presentations, including plenary papers, describing the research accomplishments of Institute scientists were given at the 1985 International Acid Rain Conference at Muskoka, Ontario.
- Watershed acidification models were developed to assess the aquatic impacts of acid precipitation and to predict geographical areas at risk.
- *Sphagnum* moss was found to be an effective biomonitor of atmospheric metal deposition. The technique is now in use in representative areas across Canada.

**Water Quality Methods Development.** In this ongoing project, new and improved analytical methodologies for the measurement of chemical and biological parameters in water, sediment and biota are developed and transferred to Inland Waters Directorate operational (and research) laboratories. National expertise in instrumentation and analysis is thereby enhanced and analytical accuracy, economy and effectiveness improved. Review period highlights are the following:

- Institute staff organized and chaired two international symposia related to microbiological methodology, the International Symposium on Aquatic Microbial Ecology and the Second International Symposium on Toxicity Testing Using Bacteria.
- Assistance was provided to the International Development Centre, Ottawa, to design and evaluate a three-continent study on the use of coliphage as an indicator of microbial water quality.



- A new method for solubilizing and measuring polychlorinated dibenzo-p-dioxins (PCDD) by a radioimmunoassay technique was calibrated, standardized and used for PCDD screening.
- A flow-injection/atomic absorption method for Ca and Mg was developed and transferred to operational use.
- A flow-injection/colorimetric method for the simultaneous determination of ammonia, nitrate, nitrite and phosphate was developed and transferred to operational use. This is more efficient and cost-effective than previous techniques.
- The traditional molybdate “geo-P” method for analyzing sediment phosphorus was modified to prevent iron (III) interference and to permit estimation of the bioavailable phosphorus fraction by chemical extraction.
- A large-volume, continuous-flow extractor was developed to concentrate organic contaminants which occur at extremely low levels in environmental samples. Units are now operational in both the field and the National Analytical Laboratory.

**Water Quality Monitoring and Modelling Research.** Improved methods of data collection, interpretation, synthesis and prediction are required for national water quality assessment. In this project, improved chemical and biological monitoring strategies, data interpretation protocols and water quality simulation models are developed for Inland Waters Directorate operational use and for interpretation of Great Lakes Surveillance data. Project highlights include the following:

- A fundamental new strategy for monitoring and interpretation of toxic chemicals in rivers was developed and transmitted to operational programs in Canada and the United States.
- A comprehensive statistical assessment of the Great Lakes Surveillance Program was completed.
- Expertise was provided to an operational reevaluation of the role and needs of sediment monitoring programs in Canada.
- A numerical model was modified to assess various phosphorus management options for the control of eutrophication in the four Qu'Appelle fishing lakes.
- An atlas of the optical properties of the Great Lakes (photic depth, PAR, etc.) was prepared.

**Lake and River Restoration.** Federal and provincial water managers require expert assistance in rehabilitating the Great Lakes and other regional lakes and rivers from the effects of nutrient eutrophication and macrophyte infestations. Applied, site-specific research is undertaken to establish cause-effect relationships and develop specific remedial plans. Project highlights are the following:

- In a joint Inland Waters Directorate–Industry study of eutrophication in the Thompson River, B.C., experimental flowing troughs were used to determine the combined effects of physical conditions and nutrient flux rates (P and N) on periphyton growth. New generalizations on organic production in rivers, with major implications for water quality management, were formulated.
- Sediment dialysis samplers (“peepers”) were used to measure regeneration and internal loading of soluble phosphorus to Lake Erie. Fifty percent of the non-apatite sediment phosphorus is potentially regenerated.
- Experiments with sediment traps showed that large quantities of phosphorus can be made available by natural resuspension of sediments in the Great Lakes.
- Experimental lime treatments to restore eutrophic Frisken and Chain lakes (B.C.) were successful. Management advice on the use of the method was provided to government agencies in British Columbia and Alberta.
- *Cladophora*, a filamentous nuisance alga affecting Lakes Ontario, Erie and Huron, was found to have declined about 50% between 1972 and 1983, due to phosphorus reductions.
- Harvesting experiments to control Eurasian milfoil in Buckhorn Lake, Ontario, were completed, and procedures to minimize adverse treatment effects developed. Numerous presentations on the impact of aquatic weeds were given to citizens' groups.
- Analysis of historical data on the recovery of Kootenay Lake, B.C., following severe phosphorus pollution, indicated only slight declines in phytoplankton and no changes in zooplankton, apparently as a result of nitrogen limitation and *Mysis* grazing. Controversial provincial plans to fertilize the lake by aircraft in an attempt to restore declining fish stocks were thus abandoned.

**Near-shore — Open-Lake Interactions.** Point-source pollutants are usually discharged or advected into the near-shore zone of large lakes, a zone that is physically distinct from the open lake. In this project, the physical and sedimentological processes controlling the movement of contaminants between the coastal and offshore zones of the Great Lakes are identified, quantified and modelled. Highlights of this project, which is nearing completion, include the following:

- A comprehensive review and several synthesis reports were published on water circulation in Lake Ontario, with emphasis on near-shore coastal zone dynamics and the transport and fate of toxic contaminants in Lake Ontario from the Niagara River plume.
- A major monograph on effluent transport and diffusion models for the coastal zone of large lakes was published.

**Water Resources and Modelling.** Management of water resources in its various aspects requires knowledge and understanding of the movements and mixing processes of water, as well as its interactions with land and air. In this project, simulation models are developed to predict the physical effects of man-made or natural alterations in the environment. Review period highlights include the following:

- The MOBED river model was modified to deal with non-uniform sizes of bed material and now simulates “paving” effects. MOBED was applied to Qu’Appelle River data to predict the response of the river to the removal of meander loops.
- The RIVMIX model was modified to predict downstream concentrations of some classes of non-conservative pollutants, such as water-soluble, but volatile compounds.
- Institute staff chaired a NATO workshop on urban pollution and contributed to UNESCO manuals on urban drainage and data acquisition.
- The flow component of the HSPF model was installed on the NWRI computer, calibrated, and used to evaluate the effects of urbanization on water quality and quantity in the Waterford River basin.

**Inter-basin Water Transfer.** To develop the interdisciplinary expertise and departmental credibility for effective assessment of future diversions, this new project will systematically identify, and, if feasible, generalize about the physical, chemical and ecological effects of large-scale inter-basin water transfers. The initial focus is on physical processes. Highlights from this subject area are the following:

- A five-year study to determine the environmental sensitivity of the large, deep, ice-covered, riverine headwater lakes of the Yukon River to future hydroelectric impoundments and diversions was completed. Baseline descriptions were provided of important physical, chemical and microbiological processes, with emphasis on circulation patterns and ice formation during winter.
- Available information on the effects of diversions on river regimes was analyzed and reviewed. Research to develop better models of river dynamics, lake erosion and ice behaviour was recommended.

**Flooding and Ice.** To improve ice-jam flood management, this ongoing project will acquire the knowledge needed to develop ice-jam forecasting methods using data on formation, transport and distribution of frazil and anchor ice. Highlights include the following:

- Field measurements of ice growth and decay, frazil dam formation and midwinter streamflow in the Yukon River were obtained in collaboration with the Water Resources Branch. Specific factors which may control ice-jam formation and spring breakup were identified.
- An improved turbulence model to predict flood levels was developed. The model takes into account changing bed roughness as well as overbank flow.
- A mathematical model of ice-jamming was improved so that it can be applied to channels of changing width.

**Fraser River Rehabilitation.** The Fraser River Estuary in British Columbia is an area of environmental degradation. In particular, the effects of chemicals used in wood processing require investigation. Pathways of transport, degradation and bioaccumulation of chlorinated phenols and related contaminants in the estuary will be determined and used as “benchmark” models for other contaminants. The knowledge will aid in the design of monitoring programs and the formulation of water quality objectives within the framework of the Fraser River Estuary Management Program. Highlights of preliminary work include the following:

- Background information was collated and preliminary field work undertaken to determine the fate and effects of chlorophenols in the estuary. Leeches were shown to be excellent biomonitors for detecting waterway contamination by chlorophenols.

**Air/Water Contaminant Exchange.** This project will determine the extent to which atmospheric loading of toxic contaminants may prolong the recovery of the Great Lakes following point-source control. Data on precipitation already reveal the importance of this pathway. Air/water contaminant flux rates will be determined from laboratory and field experiments and novel simulation models to predict aerial loadings will be developed.

- Concentrations of PCBs, alpha-BHC and lindane in rainfall were found to be relatively uniform across southern Canada, east of the Rocky Mountains.

**Fate and Effects of Pesticides.** A departmental source of expertise and a systematic information base on ecotoxic effects of pesticides is needed. This project will systematically determine the pathways, fate and effects of important diffuse-source pesticides. Both laboratory and field experiments, primarily in eastern Canada, will be carried out.

- A national survey of the extremely toxic, anti-fouling pesticide, tributyltin, in water and sediment showed its occurrence is related to boating and shipping activities, mainly in harbours and marinas. Sunlight and bacterial degradation are the main factors controlling the persistence of tributyltin, which has a half-life of several months under Canadian conditions.

**Nutrient-Contaminant Interactions.** This new project will evaluate whether the processes of bioaccumulation, biodegradation and sedimentation of toxic contaminants in lakes are controlled by the nutrient status and biological productivity of the system. An understanding of these complex interactions, which could determine the vulnerability of a particular lake to toxic pollution, will be important in the development of future contaminant action plans.

**Ground-Water Contamination.** More knowledge and expertise are required for the effective management of eastern Canadian ground-water supplies contaminated by toxic wastes and biocides. Better sampling, analytical and modelling techniques will be developed to determine the physical and chemical processes controlling the migration and fate of ground-water contaminants. This new project will focus on dump-site contamination in international reaches of the Great Lakes connecting channels and on potential contamination of potable ground-water supplies in the Maritimes.



## DIRECTOR'S OFFICE

### SENIOR SCIENTIST

Dr. R.A. Vollenweider, the Senior Scientist of the National Water Research Institute, has continued to provide scientific leadership at the Institute. He has contributed to the reformulation of NWRI research programs, and served as advisor to the Director, NWRI. He has also been elected Chairman of the DOE Senior Scientist Committee.

In recognition of his leadership in limnology, Dr. Vollenweider received the 1986 Tyler Prize for Environmental Achievement and was elected a Tyler Laureate. The Tyler Prize is one of the most prestigious environmental awards in the world. Citing Dr. Vollenweider's research on eutrophication, the Tyler Prize Executive Committee described him as the scientist most responsible for reversing pollution in the Great Lakes. In addition, Dr. Vollenweider's scientific contributions to Canadian limnology and water management were honoured by receipt of the "Frank Rigler Memorial" award from the Society of Canadian Limnologists, a biographical sketch in *The Canadian Encyclopedia* and an article in *Saturday Night*.

Dr. Vollenweider was invited as keynote speaker to three international conferences (European Water Pollution Control Association Lake Pollution and Recovery, Rome; Management Strategies for Phosphorus in the Environment, Lisbon; Living in a Chemical World — Special Conference on Lakes and Estuaries, Bologna) and has lectured at several Japanese universities (Shiga, Nagoya, Tsukuba) and Japanese governmental agencies, the University of Constance in Germany, and the Spanish Centre for Hydrographic Studies. He was also the main lecturer at a Pan American Centre for Sanitary Engineering course on Tropical lakes (Guadalajara) and continued as advisor to the Pan American Health Organization Cooperative Program on Warm Water Lakes in South America, and to the Emilia-Romagna Regional Government in Italy, on pollution of the Adriatic Sea. He has been elected as international co-president of the International Centre for Advanced Environmental Studies, Como, Italy, and as a sponsoring member of the International Lake Environment Committee, Otsu, Japan.

### SCIENCE LIAISON AND COORDINATION

The Science Liaison Coordinator (SLC), under the guidance of the Director and Management Team of NWRI, coordinates the planning and communication of the Institute's research programs.

The central focus for effective and flexible research planning within the Institute is the comprehensive Project Management System put into effect in late 1985. Research at the Institute is made up of interdisciplinary research projects focusing on priority problems or issues of national significance.

As a member of the Management Team, the Science Liaison Coordinator is responsible for ensuring the development, approval and documentation of research projects each year in an effective and timely manner. Preparation of the annual Project Directory, Annual Report, departmental Work Plan, monthly progress reports, special project brochures and other research communication documents is undertaken, or coordinated, through this office.

The SLC also assists Division Chiefs designated by the Director to oversee liaison with regional and headquarters

operational components of the Inland Waters Directorate who are principal "users" of the Institute's research results. Operational research needs are evaluated for inclusion in future projects, either by direct contacts or through established committees, and results of past work are communicated to potential users. The SLC will also be responsible for research coordination with the National Hydrology Research Institute, after it is reestablished at the National Hydrology Research Centre, Saskatoon.

Lastly, the Office of the Science Liaison Coordinator provides overall coordination of public information programs and community relations activities at NWRI, ensuring that the accomplishments of the Institute are communicated effectively and responsibly to the public at large. (Daley)

### SENIOR RESEARCH MANAGEMENT ADVISOR

A study is in progress on year-to-year variations in the development of the thermal bar in Lake Ontario from 1965 to the present. Work on a prediction scheme, first published in the early 1970s, will be updated, based largely on extensive temperature surveys carried out by the Institute.

A general review of processes that affect the quality of source water for industrial or municipal intakes around Lake Ontario was presented to the workshop on "Impacts of Source Water Quality on Industrial Processes and Municipal Uses" in Rochester, N.Y. This workshop may stimulate better communication of information about the extensive databases available on water quality in this lake.

Environment Canada liaised with the Ontario Ministry of the Environment and Dow Chemical of Canada Ltd. to assist in the cleanup of contaminated bottom sediments in the St. Clair River near Sarnia, Ontario. As senior DOE officer on site he coordinated the acquisition and interpretation of video films of the area before and after cleanup and of the dredging/vacuuming techniques used. (Rodgers)

### WHO COLLABORATING CENTRE ON SURFACE AND GROUND WATER QUALITY

The Institute is designated by the World Health Organization as its Collaborating Centre on Surface and Ground Water Quality (WHO/CC). The main functions of the WHO/CC are coordination of international technical assistance programs to developing countries and representation of Canada's freshwater interests in international forums. The WHO/CC is coordinating the establishment of a worldwide network of water quality monitoring stations on major rivers, lakes and aquifers. The network is an integral component of the United Nations Global Environmental Monitoring System (GEMS). The main objective of this program is monitoring long-term trends in environmental pollution.

The WHO/CC publishes the quarterly journal *Water Quality Bulletin*, which contains reviews of water management practices around the world. The year 1985 marked the 10th year of uninterrupted publication of the *Water Quality Bulletin*, in separate English and French editions. Over this period, approximately 400 articles from 70 countries were published. The journal is now distributed in 126 countries.



The first issue of Volume 10 was devoted to water toxicity and its effect on human health. Under the theme Toxicity Testing for Water Quality, a number of bioassaying techniques used in different parts of the world were reviewed. The three subsequent issues described the experiences of 30 countries in their national water quality monitoring programs, in particular the implementation of the GEMS/WATER program.

By the end of 1985, over 290 000 measurements had been reported to the WHO/CC Global Data Centre from 449 GEMS monitoring sites located in 60 countries. The recommendations made at the Inter-Regional Review Meeting on Water Quality Monitoring Programs in October 1983, and published in 1984 in the GEMS/WATER Data Evaluation Report, are gradually being implemented. A new GEMS/WATER data form containing a revised listing of water quality variables was distributed. Data are now also distributed on microfiche to participating countries and institutions.

During the report period, study and discussion programs for 17 visitors from Australia, Argentina, China, Japan, Morocco, Nicaragua and Sweden were organized, and requests by WHO regional and national offices for Canadian consultants abroad were processed. A variety of inquiries on water management problems particularly from developing countries were also reviewed. (*Barabas*)

## FISH HABITAT STUDIES

Some lake trout spawning habitats in eastern Lake Ontario appear to be affected by the presence of degrading organic materials. During late September and October, large quantities of *Cladophora* are broken from substrate holdfasts in shallow near-shore areas (water depths of 3–4 m) and these filaments become incorporated within the interstices of nearby cobble-gravel deposits. Later, a similar flux of fragmented milfoil may add to the organic load. Aerobic heterotrophs and nitrifying bacteria then break down these organic materials, resulting in the depletion of dissolved oxygen and the production of ammonia and CO<sub>2</sub>.

Sediment "peepers" (closed cylinders, having one end fitted with a 0.45- $\mu$ m membrane filter) were placed in the cobble-gravel substrates and allowed to equilibrate. At depths of 6–10 cm within the substrate, dissolved oxygen levels approached zero and ammonia levels reached as high as 5.5 mg-L<sup>-1</sup>. Such values indicate that the water quality at depths where naturally spawned lake trout eggs occur is potentially lethal to developing embryos. Persistence of such conditions could greatly reduce the survival of eggs from introduced lake trout stocks.

Boxes containing simulated gravel, placed flush with the surface of cobble-gravel substrates, were used to collect particulates entrapped in beach materials during late fall when lake trout spawn. Trapped sediments at two sites contained mostly inorganic sand-size particulates, high concentrations of black sulphide grains and H<sub>2</sub>S. Fall storms probably erode near-shore sand deposits containing sulphide-rich layers and the resultant fines add to the oxygen stress within the coarser substrates. During summer and early fall, plankton and *Cladophora* fragments are buried in the sandy sediments, providing ideal conditions for bacterial sulphide production.

These results are directly relevant to the success of the Great Lakes lake-trout rehabilitation program. Further studies are required to define the magnitude of potential problems in historic spawning sites and to determine the relative effect of different types of organic materials. (*Sly*)

## SPECIAL PROJECT: ST. CLAIR RIVER POLLUTION INVESTIGATION

An urgent investigation was carried out in response to the discovery of perchloroethylene puddles on the St. Clair River bottom near Sarnia, Ontario. This effort was an adjunct to the Upper Great Lakes Connecting Channels Study (UGLCCS), a large, Canada–U.S. scientific investigation of the Detroit, St. Clair and St. Mary's rivers, which began in 1984. The purpose of the UGLCC study is to determine the environmental impacts of pollution sources on these rivers as the basis for development of specific remedial action plans and a revised surveillance strategy. The project was requested by the International Joint Commission under the 1978 Canada–U.S. Great Lakes Water Quality Agreement as a means to monitor the restoration of degraded areas. NWRI has a prominent role in this study.

The National Water Research Institute together with other Environment Canada agencies, working closely with the Ontario Ministry of Environment, developed an integrated research plan for the St. Clair River to be completed and reported within six weeks. NWRI initiated intensive sediment and water surveys to define the extent of contamination in the study area while DOE and MOE sampled industrial intakes and point source discharges. Samples were also collected from the CNR St. Clair River tunnel and from the tunnel dewatering discharge. Samples were analyzed for volatile organics, chlorinated extractables, polynuclear aromatic hydrocarbons, and chlorophenols; sediments were also analyzed for dioxins. Some samples of sediment and water in the area of concern had already been collected by NWRI prior to the perchloroethylene spill. Analyses of some of these samples were accelerated for inclusion in the report. In addition, 63 cores of bottom sediment plus overlying river water were analyzed to complement earlier sampling by MOE and the University of Windsor. To assist EPS and MOE, NWRI also analyzed about half of the industrial and municipal intake/effluent samples used for source characterization.

Parallel to this contaminant investigation, NWRI was asked to aid MOE and Dow Chemical in the spill cleanup. The principal activity was the use of a video camera, mounted in a remotely controlled (cable) observation vehicle, to monitor bottom conditions during the dredging of sediments by Dow. In addition, scientific advice was provided on hydraulics and chemistry questions related to the puddle, or "blob," material.

The initial major dredging operation was completed on December 23, 1985, and the St. Clair River Pollution Investigation report was released on January 24, 1986. NWRI is responsible for following up certain recommendations of the pollution report, especially with regard to ambient conditions. Additional work is planned under the auspices of the UGLCC Study. In addition, because the puddles reformed after dredging was complete, NWRI assisted MOE with regular inspections. As the puddle sources were identified, measures to prevent loss of material downstream were put in place and revacuuming of the puddle material undertaken.

The Institute contributed greatly to the scientific aspects of the St. Clair River Pollution report, especially with respect to the "perchloroethylene" puddles, ambient sediment and water conditions, and data interpretation to pinpoint contaminant sources.

For example, the comparison by NWRI of Dow effluent data with data on the chemical composition of the puddles in the river, together with certain Dow findings, resulted in the major effort by Dow to track and eliminate the sources of contaminant on the plant site missed in earlier monitoring. The Dow response included major excavations on the plant site,

removal of one complete drain system from service, development of techniques to minimize future seepage to the river, improved monitoring, improved staff awareness of potential environmental hazards in their work, and improved systems for controlling potential spills and contaminated runoff.

Institute research has also pinpointed other sources of perchloroethylene, volatiles and hex tars along the shore of the river and has clearly shown that contaminants released at the Canadian shore show little, if any, transport across the Canada/U.S.A. boundary within the 8- to 10-km stretch of the St. Clair River studied.

Finally, NWRI work on urban runoff and on mass transport of materials down the river, in conjunction with point-source data, has allowed critical judgements to be made on the relative importance of various sources along the river and on the fate of released chemicals. (Rodgers, Lawrence).

## STAFF LIST

**Director — D.L. Egar, B.Eng., M.Sc.**  
**Secretary — M. Stapleton**  
**Receptionist — A. Caswell**

<b>Senior Scientist</b>	R.A. Vollenweider, B.Sc., M.Sc., Ph.D.
<b>Assistant</b>	L. Janus, B.Sc., M.Sc.
<b>Science Liaison Coordinator</b>	R.J. Daley, B.A., M.Sc., Ph.D.
<b>Senior Research Management Advisor</b>	G.K. Rodgers, B.A.Sc., M.Sc., Ph.D.
<b>Research Scientist</b>	P.G. Sly, B.Sc., Ph.D., P. Eng.
<b>WHO Collaborating Centre Manager Secretary</b>	S. Barabas, Ph.D. S. Ponton

## COMMITTEE MEMBERSHIP

Mr. D.L. Egar  
 Member, Great Lakes Working Group  
 Member, IWD Research Subventions Committee  
 Member, St. Clair River Management Committee  
 Member, Upper Great Lakes Connecting Channels Management Committee  
 Member, Editorial Board, *WHO Water Quality Bulletin*

Dr. G.K. Rodgers  
 Vice-Chairman, Council of Great Lakes Research Managers, International Joint Commission  
 Member, Editorial Board, *WHO Water Quality Bulletin*  
 Member, Activity Integration Committee for the Upper Great Lakes Connecting Channel Study

Dr. R.A. Vollenweider  
 Chairman, DOE Senior Scientist Committee  
 Member, Departmental Committee for the Scientific Research Group  
 International Co-president, International Centre for Advanced Environmental Studies (ICAES)  
 "Alessandro Volta," Como, Italy  
 International Lake Environment Committee (ILEC), Otsu, Japan — Promotor and Member  
 Advisor to CEPIS/PAHO, Lima, Peru on "Latin American Cooperative Programme on Eutrophication in Warm Water Lakes and Reservoirs"  
 Fellow, Rawson Academy  
 Member, Editorial Board of "Memorie dell'Istituto Italiano di Idrobiologia," Verbania-Pallanza, Italy  
 Member, Editorial Board, *WHO Water Quality Bulletin*  
 Member, Scientific Advisory Committee "Cervia Ambiente," Italy

## PUBLICATIONS

Janus, L.L., and R.A. Vollenweider. 1984. Phosphorus residence time in relation to trophic conditions in lakes. *Verh. Int. Ver. Limnol.*, 22.

Sly, P.G. 1984. Habitat. In CLAR (Strategies for rehabilitation of lake trout in the Great Lakes), Great Lakes Fishery Commission Tech. Rep. No. 40.

Sly, P.G. 1984. Sedimentology and geochemistry of modern sediments in the Kingston basin of Lake Ontario. *J. Great Lakes Res.*, 10: 358-374.

Sly, P.G., and W.J. Prior. 1984. Late glacial and post glacial geology in the Lake Ontario basin. *Can. J. Earth. Sci.*, 21: 802-821.

Sly, P.G., and C.C. Widmer. 1984. Lake trout (*Salvelinus namaycush*) spawning habitat in Seneca Lake, N.Y. *J. Great Lakes Res.*, 10: 168-189.

Sly, P.G. 1986. A review of post glacial environmental changes and cultural impacts in the Bay of Quinte. In *Project Quinte* (C.K. Minns, D.A. Hurley and K.H. Nicholls, eds.), Special Pub. No. 86, Can. J. Fish. Aquat. Sci. In press.

Sly, P.G. 1986. Disturbance of lacustrine systems. In *Lakes and Limnology* (K.J. Gregory and D.E. Walling, eds.), John Wiley and Sons Ltd., Chichester, England. In press.

Vollenweider, R.A. 1985. Phosphorus, the key element in eutrophication control. *Proc. Int. Conf. Management Strategies for Phosphorus in the Environment* (J.N. Lester and P.W.W. Kirk, eds.).

Vollenweider, R.A. 1985. The scientific knowledge of lake pollution. (Abstract). *Proc. Int. Conf. Lakes Pollution and Recovery*. (E. de Fraja and R. Vismara, eds.).

Vollenweider, R.A. 1985. Elemental and biochemical composition of plankton biomass: Some comments and explorations. *Arch. Hydrobiol.*, 105, 1.

Vollenweider, R.A. 1985. Environmental research in the private sector: Implications for Canada. Internal report.



## AQUATIC ECOLOGY DIVISION

The Aquatic Ecology Division is made up of specialists in the fields of limnology and paleolimnology, microbiology, geochemistry, algal and invertebrate ecology, statistics and plant physiology. The Division addresses departmental issues related to environmental degradation and ecosystem health, particularly in the area of nutrient and contaminant control, lake restoration, acidification, management of aquatic weeds, and water quality monitoring (both chemical and biological). The Division is organized in three multidisciplinary sections: Ecological Impact, Great Lakes Rehabilitation, and Nutrient Pathways.

### ECOLOGICAL IMPACT SECTION

The Ecological Impact Section conducted research in the following areas: long-range transport of atmospheric pollutants (LRTAP) with emphasis on geochemical aspects of lake acidification, peatland development and its impact on water quality, paleolimnology, and statistical methodology for water quality interpretation. The LRTAP-related studies dealt with the use of sulphur isotopes as tracers; metal profiles in sediment cores and the release of metals from sediment upon acidification; the characterization of natural acidity; and the use of diatoms as paleolimnological indicators of pH and of *Sphagnum* moss as a bioindicator of atmospheric deposition of metals. The emphasis of the peatland study was the ecological impact of the mining of peatlands on the receiving waters. One paleolimnological study concentrated on the use of proxy climatic data.

**Lake Acidification.** The sources of sulphur pollution and the sulphur reactions resulting in endogenous production of alkalinity in lakes are critical issues in the current debate about acid rains and lake acidification. The variations in the isotopic signature of the sulphur can, in fact, be used to fingerprint its sources and trace its behaviour in softwater lakes. In the Turkey Lakes watershed, pronounced seasonality in the isotopic composition of bulk precipitation was found. The observed depletion in  $^{32}\text{S}$  suggests a significant contribution of biogenic sulphur to the atmospheric sulphur loading in the region. The isotopic composition of the lake water, however, shows no comparable seasonal variation and, on an annual basis, is very close to the mean value for the bulk precipitation. Most of the sulphur stored in the lake sediments is in the reduced form, mostly as organosulphur compounds. The conversion of pollutant sulphate to the reduced forms is believed to be an important process which is generating significant quantities of alkalinity in this watershed. (*Nriagu*)

Lake sediment often maintains a historical record of the recent increase in the flux of toxic metal pollution into the lake basin. Such sedimentary metal reservoirs can become mobilized and released to the water column during lake acidification.

From the  $^{210}\text{Pb}$  dating of the sediments, the historical changes in the accumulation of pollutant metals since 1910 have been determined. Metal depositional rates in lakes in

Nova Scotia are comparable with those of the remote lakes in Ontario (Algonquin Provincial Park) and the Adirondack Mountain lakes (New York).

A simple mass conversion model based on rare earth elements suggests that only 40% to 60% of the pollutant metal flux into lakes is retained by the sediment. The low retention rate can explain the large intra-basin and intra-lake variations in metal content of sediments and has major implications in terms of  $^{210}\text{Pb}$  dating and the use of pollutant metal profiles in the historical monitoring of environmental changes associated with acid rains.

To characterize the chemical interaction between the dissolved and particulate metal species along a pH gradient, pore water (*in situ*) was sampled at close intervals above and below the sediment-water interface from two acid lakes in Kejimikujik National Park, Nova Scotia. Concentrations of selected pollutant metals including Pb, Zn, Fe, Al, nutrients and rare earth elements were measured. Preliminary data for  $\text{SO}_4$ , Al and  $\text{PO}_4\text{-P}$  in the pore water show a close relationship between pH and the nutrient cycles in the lake sediment column. Relationships between trace metal profiles and hydrogen ion pro-

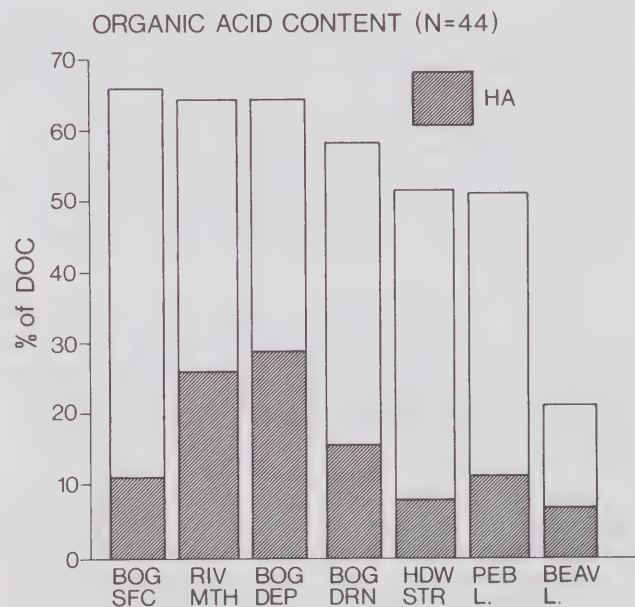


Figure 1. Sum of organic acid fractions from naturally acidic waters. Total height of bars = Fulvic acid (hydrophobic + hydrophilic) + humic acid. BOG SFC — interstitial bog water, 0 – 75 cm. RIV MTH — rivers near their mouths; BOG DEP — interstitial bog water, 1.25 – 2.0 m; BOG DRN — bog drainage creek; HDW STR — headwater streams; PEB L. — Pebbleloggitch Lake, coloured; BEAV L. — Beaverskin Lake, clear; HA — humic acid.



duction/consumption are currently being investigated. (Nriagu, Wong)

Natural acidic waters were also studied to understand the effects of anthropogenic acidification of aquatic systems. A comprehensive study of the character of naturally occurring organic acids present in lakes and rivers in southwestern Nova Scotia has been undertaken. Results of seasonal sampling from several sites in Kejimikujik National Park and the Mersey and Clyde rivers indicate that the character of dissolved organic matter (DOM) changes with the annual hydrologic cycle. Most of the DOM can be classified as fulvic acid, the bulk of which consists of hydrophobic acids. Figure 1 shows the relative acidic character of some of our samples grouped by sample type. Near the mouths of rivers, a marked increase in the relative amounts of humic acid is evident. As humic acid is thought to be a diagenetic product of condensation reactions involving fulvic acid (fractions), this may be evidence that changes of character occur along the course of rivers. These changes may in turn affect the metal-binding capacity, acid strength, and lability of the DOM. (Bourbonniere)

**Acidification History.** The spatial variability in diatom frustules as paleoindicators of lake acidification was described for three Precambrian Shield lakes in the Dorset region of southern Ontario.

Three statistical approaches were used to determine the amount of variability in the surface diatom assemblages of the three study lakes: (1) cluster analysis, (2) single and multivariate analysis of variance, and (3) analysis of variance components. The results, mutually collaborative, indicated that all three lakes had a significant amount of heterogeneity in the species composition of their surface diatom assemblages. Hence, one or a small number of random samples cannot adequately represent the "average" diatom flora of a lake. Samples regarded as being most representative of the whole lake occurred in the flat profundal regions located away from the deepest sediments. Factors influencing the species distributions included habitat characteristics, basin morphometry and allochthonous sources of diatoms. (Glooschenko)

Studies on the paleolimnology of acid susceptible lakes have been completed. The diatoms of the Turkey Lakes system show little, if any, impact by atmospheric loading in the area. (Delorme)

**Atmospheric Transport of Pollutants.** Studies have been conducted on the use of *Sphagnum* moss as a biomonitor of the atmospheric deposition of metals. Previous work has concentrated on point sources of metals in Ontario and Quebec, with emphasis on the smelters at Sudbury and Rouyn-Noranda. Also, background levels of metals were determined in remote areas of Ontario. In general, eastern Canadian mosses exhibited high contents of metals except in northern remote areas such as the Hudson Bay Lowland, the lower St. Lawrence River Valley and Labrador. This increased metal level in eastern Canada is undoubtedly related to the high urbanization and industrialization in the area. Sampling has been extended to boreal sites in western Canada from Manitoba to coastal British Columbia, and as far north as Yellowknife, N.W.T. Preliminary results indicate that metals are low and similar in concentration to those in remote, northern areas of eastern Canada. Exceptions included sites located near the smelters at Flin Flon and Thompson, Manitoba. Especially noticeable was lead, which was approximately one-quarter the level found in eastern sites and indicative of lower automobile density in western Canada. This study shows that *Sphagnum*

mosses serve as valuable biomonitors of metal deposition. (Glooschenko)

**Peatland Drainage.** The utilization of peatlands for fuel or horticultural purposes is becoming more extensive in Canada. These activities involve the drainage of bogs prior to harvesting. Local modifications of the hydrologic regime may cause significant changes in water quality downstream, which can have an adverse ecological impact. Two sites were chosen to study such effects: Barrington Bog, Nova Scotia, and Sept-Îles, Quebec. At Barrington Bog, seasonal samples were taken from a proposed fuel peat harvesting site, its natural drainage creek, and the estuary into which it flows. At Sept-Îles, samples were obtained from three bogs and their drainages which were at differing stages of development for horticultural peat.

Dissolved organic matter (DOM) that drains from these bogs is predominantly acidic and can be classified as fulvic acid. The DOM in pore waters from deeper layers of the peat contains a greater proportion of humic acid. During periods of low flow (dry summer), the humic acid content of the natural drainage waters is increased relative to wetter periods. This suggests that drainage during drier periods comes from a greater depth in the bogs, exactly what would be expected following ditching. This change in character of the DOM in bog drainage may affect its acid strength, metal-binding capacity, and lability.

Profiles of major and minor elements were determined in pore water samples from a coastal bog (Barrington) and a continental bog (Ontario). Bog waters are depleted in Na, K, Ca and Mg relative to "normal" freshwaters. This fact coupled with their high DOM content means that bog waters are ideally suited for formation of metal-organic complexes. (Bourbonniere, Glooschenko)

**Paleolimnology.** During the past two summers, 12 cores have been collected from small lakes in Saskatchewan and Alberta. The study is supported by the Canadian Climate Program. The goal is the development of climatic proxy data to investigate the relationship between surface water chemistry and climate. The core from Humboldt Lake, Saskatchewan, shows five wet periods in the past 120 years (Fig. 2). This was preceded by three periods when total dissolved solids increased by 88%. (Delorme)

**Statistical Analysis of Water Quality Data.** For many environmental issues, such as lake and river water quality, toxic substances and acid rain, a common element is the need to know whether conditions have changed. The role of statistics is crucial here because there exist a number of sources of variation, and the apparent level of change must be compared with an appropriate level of variability. The results have been of two types: data analysis, and method development and identification. Pollen and diatom concentrations in sediment cores have been analyzed for changes with depth. Toxic contaminant data have been analyzed, and on the basis of three sets of data, it was concluded that an increase in loading of contaminants to the Niagara River is occurring between Fort Erie and Niagara-on-the-Lake. A procedure for grouping multiple depth profiles on the basis of similar form has been developed and this should permit statements about change with depth to be made for homogeneous groups of profiles. To facilitate statistical analyses, a Fortran program for estimating abrupt changes has been made available in a report, and a collaborative project has been undertaken to prepare a data analysis and presentation manual for the Water Quality Branch. (Esterby)

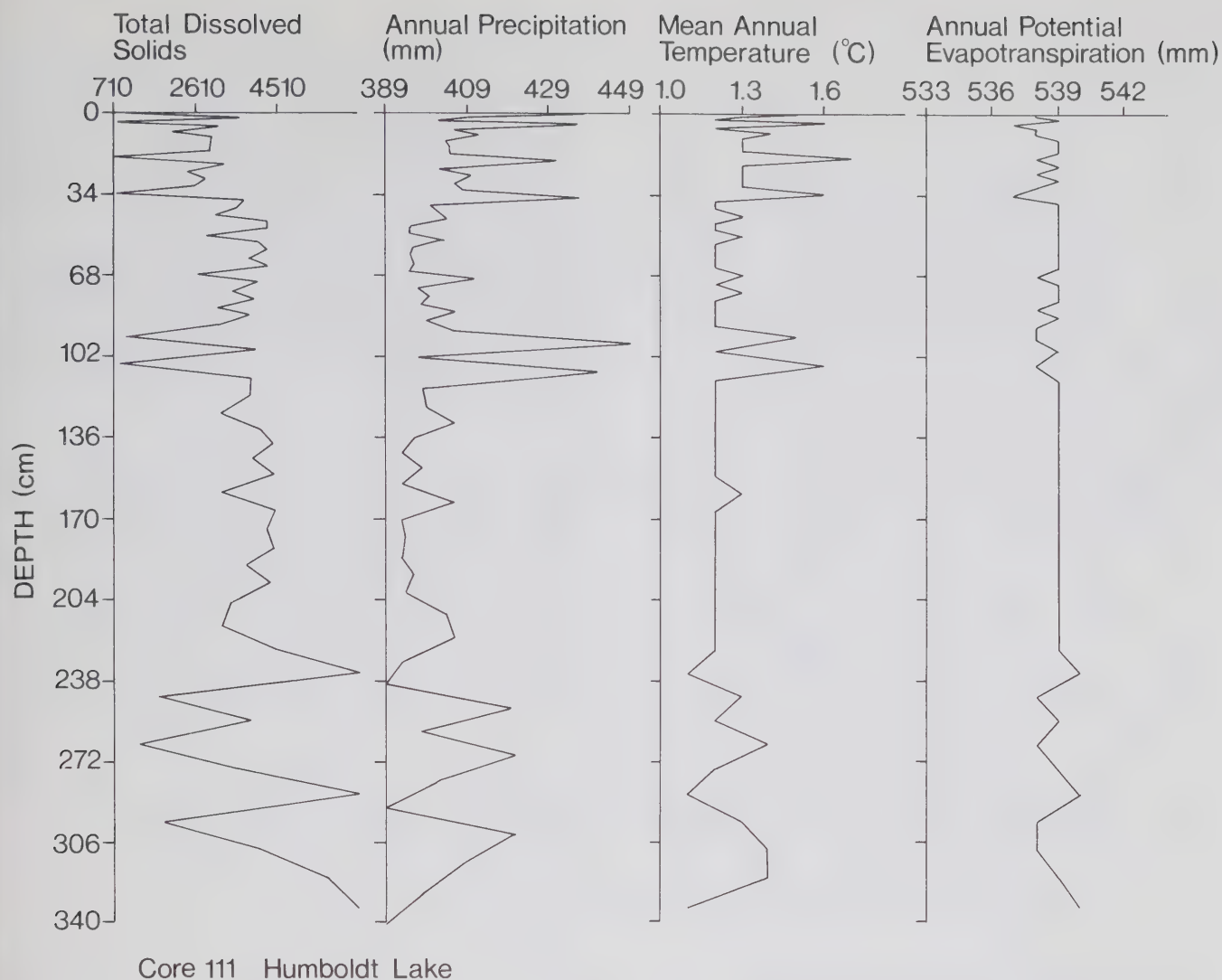


Figure 2. Comparative interpretive profiles of total dissolved solids with three climatic parameters for a core from Humboldt Lake, Sask.

## GREAT LAKES REHABILITATION SECTION

The Great Lakes Rehabilitation Section continued work on research projects related to the Canada-U.S. Agreement on Great Lakes Water Quality. Projects included work on internal nutrient loading of lakes, availability of non-point phosphorus loads, oxygen in Lake Erie, trends in Lake Erie water quality, nutrient and contaminant movement in the St. Lawrence River and Lake St. Clair, and the ecology and potential control of nuisance macrophytes.

**Lake Erie.** A compilation of historic water quality data continued as a way of documenting the eutrophication cleanup carried out under the Agreement. The oxygen depletion in the bottom layer of the Central Basin has been of concern for many years and could be expected to improve under present controls but become worse if controls were relaxed. Our research has shown that oxygen levels at the end of the summer depend greatly on the weather. Figure 3 shows that there has not been a clear trend to higher oxygen levels over the last 15 years of nutrient reductions. Surveys conducted using our NWRI profiling equipment revealed widespread low oxygen conditions in 1985 owing to prolonged stratification. On the

other hand, algal populations measured by chlorophyll have decreased by 38% from 1969 to 1978. Transparency, like oxygen, is quite variable, but the offshore waters permit visibility of a Secchi disk to a depth of 7 m, which is more than acceptable for recreational use. The NWRI oxygen/temperature profiler performed well in 1984/85. A calibrating water bath was constructed and engineering developments progressed toward an expanded prototype incorporating turbidity, conductivity and pH sensors. (Dobson, Charlton)

The response of lakes to nutrient loading changes depends on storage and release mechanisms in the sediments. Experiments with sediment traps have shown that large quantities of phosphorus are made available by natural resuspension of sediments. A new effort was made to quantify the internal loading by diffusion of soluble nutrients. Dialysis samplers were installed in the lake bottom and permitted to equilibrate with the pore water before they were removed for chemical analysis. Results (Fig. 4) show that soluble phosphorus (SRP) is regenerated at very high concentrations in the sediments. These regeneration processes may supply significant amounts of phosphorus to the lake water. A statement of the overall importance of internal loading is being prepared. (Rosa)



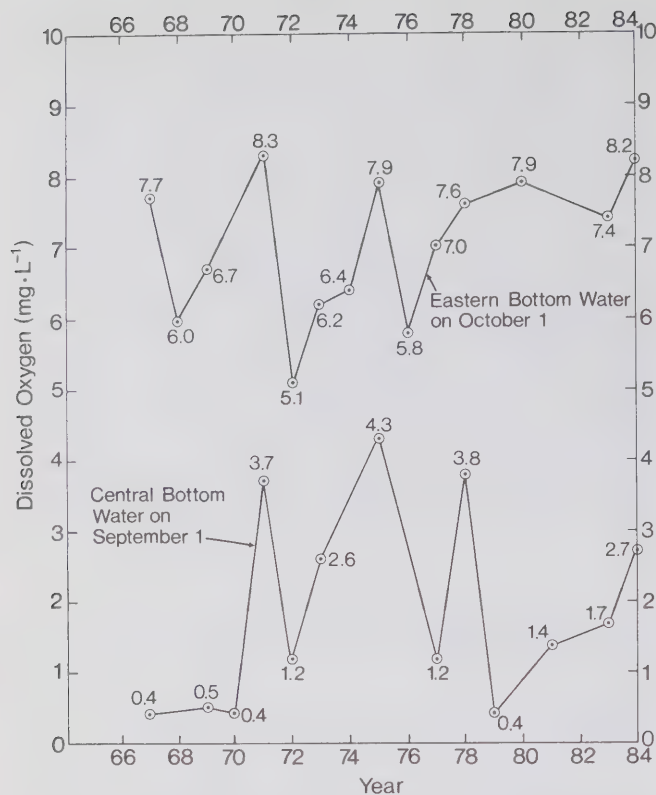


Figure 3. Dissolved oxygen in central and eastern Lake Erie; mean values in the bottom waters in late summer of each year.

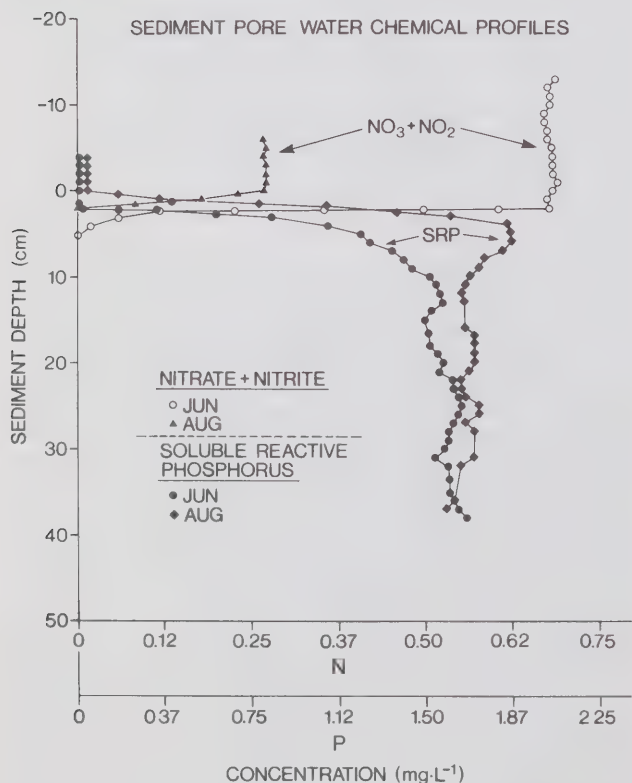


Figure 4. Regeneration of pore water soluble reactive phosphorus (SRP) and hypolimnion nitrogen during stratification in Lake Erie.

**Sediment Chemistry.** Studies of sediment phosphorus forms have shown that approximately 50% of the non-apatite phosphorus (NAIP) can potentially be regenerated. Over the last five years, the oxidation status of Lake Erie sediments has improved. This suggests that while regeneration due to anoxia should become less frequent, an anoxic situation would result in massive release. Lake Ontario sediments in the Kingston Basin were more reduced than Lake Erie sediments. The binding capacity of Lake Ontario sediments is about 3500 t·yr<sup>-1</sup>, which is consistent with target phosphorus loads. Studies of iron-sulphur compounds in lakes of British Columbia and Alberta have revealed that in Figure Eight Lake, the use of copper-based algicides resulted in the disruption of normal sulphate-reducing bacteria in the bottom sediments. This changed iron-sulphur-phosphorus relationships in the water. (Manning)

**Lake St. Clair.** As part of the Canada/Ontario/U.S. Upper Great Lakes Connecting Channels Study, a sediment trap study and water quality surveys were conducted in Lake St. Clair in 1985. The sediment traps collected samples of contaminated suspended sediments. The rate of accumulation in the traps was much higher than in deep lakes, which means that most of the particulate material in the water is derived from resuspended sediments. The study was coordinated with members of the Aquatic Physics and Systems Division, Hydraulics Division and Environmental Contaminants Division. Analyses of contaminants in the samples will be related to industrial effluents in the St. Clair River. (Charlton, Dobson)

**St. Lawrence River.** In cooperation with the Environmental Contaminants Division and Inland Waters Directorate—Quebec Region, a survey of benthic invertebrates was conducted in the St. Lawrence River between Cornwall and Trois-Rivières. A sparse but diverse fauna was found at most sites. A collection of large clams was returned to the laboratory for contaminants analysis. The St. Lawrence carries a considerable suspended sediment load and this was sampled using sediment traps. Despite the currents, the traps caught enough sediment for analyses of moving contaminants. The sediment traps proved to be an efficient way of collecting integrated suspended sediment samples. (Charlton)

**Macrophytes.** The invasion of lakes by Eurasian watermilfoil has created aesthetic damage and reduced recreation opportunities. The ecologically sound control technology of harvesting has not achieved long-term control. Short-term harvesting experiments have demonstrated control extending only to the year after harvesting; long-term experiments were necessary to determine whether the efficacy of harvesting could be enhanced. From 1981 to 1984, we conducted a double harvest each year in a 2-ha plot in Buckhorn Lake, Ontario. A reduction in biomass was achieved (Fig. 5). The areal density of milfoil plants decreased and individual plants were smaller. Effects on tissue chemistry and sediment chemistry were observed. The results of these experiments were interpreted and included in a report, the subject of which was how to maximize the control effect of harvesting.

The nuisance alga, *Cladophora*, grows in rocky shoreline areas of Lakes Ontario, Erie and Huron. Storm events can result in aesthetically unpleasant accumulations on beaches. *Cladophora* was sampled in Lake Ontario during 1972 and again in 1982/83 to determine whether the phosphorus control program had resulted in a reduction of *Cladophora* productivity. The lakewide average biomass had decreased by 58% and the lakewide average tissue phosphorus had decreased by 59%. The tissue phosphorus concentrations did not limit growth in 1972 but were low enough to limit growth in 1982/83.

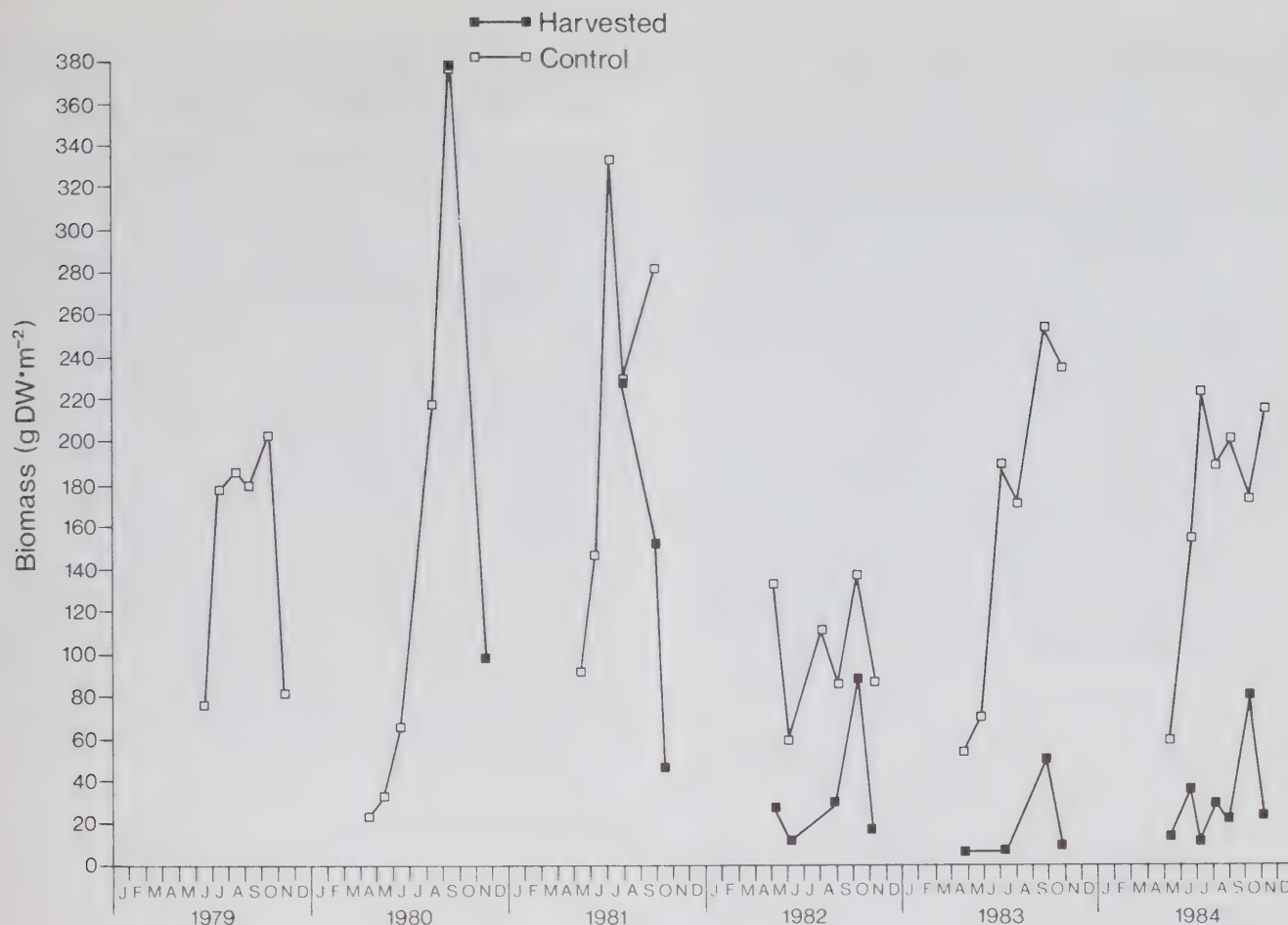


Figure 5. The effect of harvesting on milfoil biomass. DW — dry weight.

Numerous presentations were made to citizens' groups concerned with the impact of macrophytes on their usage of water resources. Predicted growth rates are now also limited by tissue phosphorus (Fig. 6). (Painter)

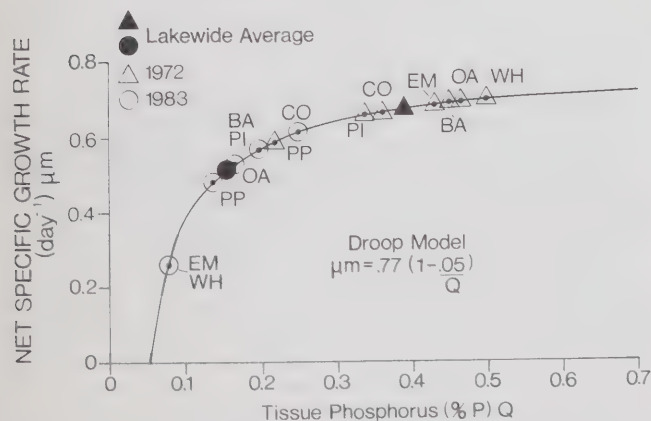


Figure 6. 1972 and 1983 tissue phosphorus in relation to Auer and Canale nutrient-growth model. For symbols see Painter and Kamaitis (1985) in list of publications at end of section.

## NUTRIENT PATHWAYS SECTION

The Nutrient Pathways Section continued to research lake restoration techniques, taste and odour problems in municipal water supplies, the effect of toxic substances and nutrients on biological processes (i.e., algal and bacterial productivity and metabolic activities), and the functional roles of selected organic substances found in lake waters.

**Microbial Ecology.** The effect of certain heavy metals on the metabolic activities ( $^3\text{H}$ -thymidine incorporation into DNA) of the natural bacterial population found in Hamilton Harbour was tested. The organisms were found to be very sensitive to mercury ( $\text{EC}_{50} = <0.001$  ppm) and copper ( $\text{EC}_{50} = 0.027$  ppm). The organisms were affected to a lesser degree with aluminum and cadmium ( $\text{EC}_{50}$ 's of 0.29 and 1.40 ppm, respectively). The incorporation of thymidine was not affected by the presence of 50 ppm atrazine. A DNA purification procedure was modified and used to improve the accuracy of bacterial productivity determinations. (Burnison)

One of the highlights in this field was the International Symposium for Aquatic Microbial Ecology held at the Canada Centre for Inland Waters on May 13–15, 1985. Thirty-five speakers from nine countries presented their current research interests. (Burnison, Rao—Analytical Methods Division)

**Natural Organics.** Colloidal fibrils in lake water were investigated for their capacity to form organic coatings. Suspended



organic particles ( $>5\text{-}\mu\text{m}$  diameter) usually displayed an external coating of fibrils. In the interior of complex mixed particles (whose size was the consequence of the aggregation of smaller particles), fibrils were identified as the adhesive material between smaller particles. Thus fibrils appear to modulate sedimentation of smaller particles by two mechanisms: (1) as a surface "lubricant" to affect drag reduction and (2) as a natural "glue" to facilitate flocculation. From this information one can speculate that many particle-contaminant interactions cannot be modelled properly unless fibril modulation of the interactions is considered. In a joint Aquatic Ecology Division–University of Geneva study, a technique was devised to isolate an undegraded fulvic acid fraction from lake water. Using purified isolates of the native fulvic acid, the aggregation properties (loss from solution onto surfaces) of this metal-complexing substance were characterized. Using physico-chemical techniques, colloid formation was described in terms of changes in molecular weight, degree of hydration and fulvic-fulvic acid interactions. Surface-facilitated dehydration was revealed as the mechanism for the formation of organic colloidal coatings from fulvic acids in the dissolved state. The improved understanding of these mechanisms may permit new insight into metal speciation changes in aquatic ecosystems and into design schemes for fractionating lake water by ultrafiltration. (Leppard)

In cooperation with the Water Quality Branch, Western and Northern Region, and the city of Regina, Saskatchewan, sampling and analysis for taste and odour compounds were carried out on the local water supply during the summer of 1984. The results were incorporated into a larger study commissioned by the cities of Regina and Moose Jaw prior to commencement of granulated activated carbon filtration at the Buffalo Pound Water Treatment Plant (BPWTP) for taste and odour removal. The city of Regina was also interested in spatial variations of taste and odour compounds throughout the city to determine whether they could be produced in the distribution system. Quantitative analyses for geosmin and 2-methylisoborneol were carried out on samples from the distribution system and on the raw and finished water from the BPWTP. Geosmin was detected in most samples, while 2-methylisoborneol was absent. Maximum concentrations occurred in late August (Fig. 7). The higher concentrations observed in the finished water may be explained by (1) the analytical method giving lower recovery of geosmin from raw water sam-

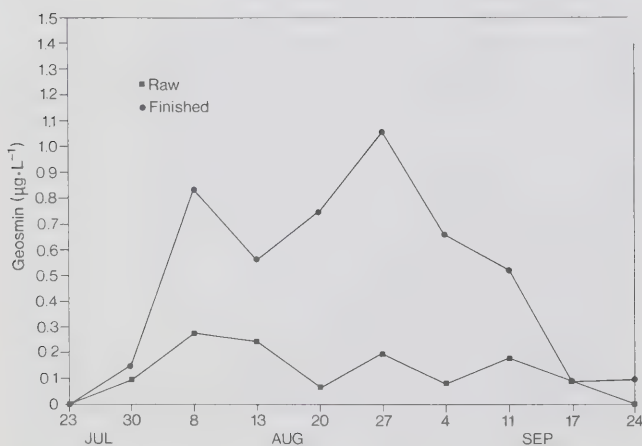


Figure 7. Geosmin concentration in raw and finished water from Buffalo Pound Lake, Sask., 1984.

ples or (2) geosmin being released from algal cells which break open during the water treatment process. Current evidence supports this latter possibility. (Brownlee)

**Lake Restoration.** Advice on lake restoration techniques has been given to various provincial agencies for a number of lakes. Understanding the cycling of iron in lakes is very critical in the selection of the proper method of restoration. Studies on Frisken and Chain lakes, British Columbia, have shown that both lakes have sediments rich in pyrite. The formation of pyrite is thought to contribute to the establishment of iron limitation common in lakes on the Thompson Plateau, B.C. The lime treatments of Frisken Lake in 1983 and 1984 have had a long-term effect on improving water clarity. Figure 8 shows that phosphorus concentrations were lower than pre-treatment values and similar to data from the summer the lake was treated. Chlorophyll concentrations were lower than pre-treatment but not as low as the summer the lake was treated (blue-green algal blooms were blocked throughout the summer of 1984). Lime treatment also resulted in a 50% reduction in the dissolved organic carbon (DOC) in the lake water. The removal of the DOC resulted in an enhanced efficiency of lime treatment. In Figure Eight Lake, Alberta, which had previously been treated with copper sulphate, analyses indicated that pyrite formation had been restricted and bacterial assimilation of acetate suppressed in the lake sediments. Copper toxicity is thought to be the cause of the amphipod collapse and chironomid avoidance of the surface sediments. (Murphy)

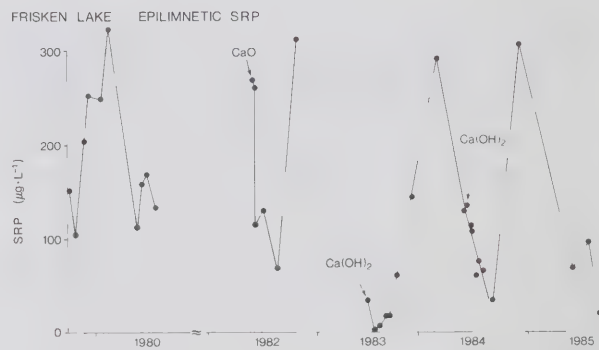


Figure 8. Epilimnetic soluble reactive phosphorus (SRP) concentration in Frisken Lake, B.C.

**Nutrient Limitation.** A joint Aquatic Ecology Division–Aquatic Physics and Systems Division collaboration on Lake Ontario integrated the influence of wind and temperature on currents and stratification patterns with nutrient studies (Water Quality Branch–Ontario Region, and the Aquatic Ecology Division). Seasonal patterns for nutrient changes were observed across a transect crossing the lake from Port Hope. Physiological indicators for phosphate deficiency were compared to determine the duration and degree of phosphate limitation of phytoplankton growth. Rates of regeneration of nutrients by zooplankton grazing were calculated and the size spectrum of the plankton related to the degree of nutrient deficiency. The rates of recycling of phosphorus within the trophogenic zone were calculated and a detailed flow diagram was prepared. A special issue of the *Canadian Journal of Fisheries and Aquatic Sciences* (in preparation) will contain articles relating to Lake Ontario nutrient assessment. (Lean)



## STAFF LIST

Chief — J.M. Barica, B.Sc., M.Sc., Ph.D.  
 Secretary — M. Jurkovic  
 Administrative Officer — F. Boyd

### Nutrient Pathways Section

#### Head

B.K. Burnison, B.Sc., M.Sc., Ph.D. microbial ecology, biochemistry of lake colloids

#### Researchers

A. Abbott, B.Sc. phosphorus kinetic studies and data analysis  
 B.G. Brownlee, B.Sc., M.Sc., Ph.D. taste and odour compounds, nutrients  
 D.R.S. Lean, B.Sc., Ph.D. ecosystem engineering, phytoplankton physiology  
 G.G. Leppard, B.A., B.S., MA., M.S., M.Phil., Ph.D. aquatic biophysics, ultrastructure of lake colloids  
 T.P. Murphy, B.Sc., M.Sc. limnology, lake restoration

### Visiting Scientist

H.J. Fricker, Ph.D. zooplankton grazing, size fractionation

### Technical Staff

K. Edmonson, B.Sc.  
 G.A. MacInnis, B.Sc.  
 D.J. Nuttley  
 D. Urciuoli, B.Sc.

### Great Lakes Rehabilitation Section

#### Head

M.N. Charlton, B.Sc., M.Sc. lake productivity, oxygen, sedimentation

#### Researchers

H.F.H. Dobson nutrient regime  
 L.L. Kalas, B.Sc., M.Sc., Ph.D. benthic ecology  
 P.G. Manning, B.Sc., Ph.D. sediment-water interactions  
 D.S. Painter, B.Sc., M.Sc. aquatic macrophytes ecology  
 F. Rosa, B.Sc. oxygen, particle settling, resuspension, Lake Erie

### Technical Staff

W.G. Booth  
 T. Mayer, M.Sc.  
 J. Wood, B.Sc.

### Volunteers

Lise Parent  
 Dirk Roels  
 Angela Bianchi

### Ecology Impact Section

#### Head

W.A. Glooschenko, B.Sc., M.Sc., Ph.D. wetlands ecology, sediment geochemistry, peat impact

S.R. Esterby, B.A., Ph.D. applied statistics, specialization in limnology and ecology  
 (as of September 1/85)

### Researchers

R.A. Bourbonniere, B.A., M.Sc., Ph.D. organic geochemistry  
 L.D. Delorme, B.A., M.Sc., Ph.D. paleolimnology  
 J.O. Nriagu, B.Sc., M.S., Ph.D. geochemistry, cycling of trace metals and sulphur in aquatic ecosystems  
 H.K.T. Wong, B.Sc. geochemistry, geochronology

### Post Doctoral Fellow

Y.K. Soon, Ph.D. soil chemist, nutrient cycling  
 D. Holdway, B.Sc., M.Sc., Ph.D. geochemistry

### Technical Staff

R. Coker  
 N. Harper, B.S.  
 L.D. Holloway, B.Sc.

### Volunteer

Johanne Legault, B.Sc.

## COMMITTEE MEMBERSHIP

#### J. Barica

Editorial Board, *Water Pollution Research Journal of Canada*  
 Canadian National Representative, SIL/SCL  
 Great Lakes Working Group, Eutrophication Issue Group  
 Plains Aquatic Research Group, Executive Committee  
 Symposia Group, Canadian Committee IAWPRC  
 Editorial Board, *WHO Water Quality Bulletin*

#### R.A. Bourbonniere

Peat Environmental Committee

#### B.K. Burnison

CCIW Radionuclide Control Committee  
 Editorial Board, *WHO Water Quality Bulletin*  
 International Symposia on Aquatic Microbial Ecology — Co-Chairman

#### M.N. Charlton

Lake Erie Surveillance Task Force  
 Lake Superior Surveillance Task Force  
 IOC Surveillance Work Group  
 COA Surveillance Subcommittee  
 Associate Editor, *Journal Great Lakes Research*  
 Board of Directors, International Association for Great Lakes Research

**L.D. Delorme**  
 International Union for the Conservation of Nature  
 IUCN Survival Service Commission  
 Canadian Committee on Climatic Fluctuations  
 and Man  
 Task Force on Proxy Data  
 Atmospheric Environment Service, Inland Waters  
 Directorate contact person for the Carbon Dioxide  
 Committee

**S.R. Esterby**  
 Canadian Committee on Climatic Fluctuations  
 and Man

**W.A. Glooschenko**  
 DOE Peat Environmental Committee, Chairman  
 1985/86  
 Editorial Board, *Geoscience Canada*  
 DOE Coral Group  
 National Wetlands Working Group  
 Canadian Committee on Ecological Land  
 Classification  
 Society of Wetland Scientists — President 1983/84;  
 Canadian representative since 1985

**D.R.S. Lean**  
 Standard Methods Advisory Group

**S. Painter**  
 Aquatic Plant Harvesting Guidelines Committee  
 Aquatic Plant Management Society, local chapter's  
 committee

**J.O. Nriagu**  
 Canadian National Committee for SCOPE  
 SCOPE Scientific Committee on Metal Cycles  
 International Committee for Symposia on  
 Environmental Biogeochemistry  
 Editorial Board, *Chemical Geology*  
 Editorial Board, *Tellus*  
 Associate Editor, *Science of the Total Environment*  
 Editor, *Advances in Environmental Science and  
 Technology*  
 Editorial Board, *Reclamation and Revegetation  
 Research*  
 NRC Associate Committee on Scientific Criteria for  
 Environmental Quality, Subcommittee on Heavy  
 Metals

## PUBLICATIONS

Anderson, J.E., A.H. El-Shaarawi, **S.R. Esterby**, and T.E. Unny. 1984. Dissolved oxygen concentrations in Lake Erie (U.S.A.—Canada), 1. Study of spatial and temporal variability using cluster and regression analysis. *J. Hydrol.*, 72: 209–229.

**Brownlee, B.G., D.S. Painter**, and R.J. Boone. 1984. Identification of taste and odour compounds from western Lake Ontario. *Water Pollut. Res. J. Can.*, 19: 111–118.

Carignan, R., and **D.R.S. Lean**. Lake chemistry as influenced by diffusive fluxes of dissolved substances across the sediment-water interface of a seasonally anoxic lake. *Limnol. Oceanogr.* In press.

Carignan, R., and **J.O. Nriagu**. 1985. Trace metal deposition and mobility in the sediments of two lakes near Sudbury, Ontario. *Geochim. Cosmochim. Acta*, 49: 1753–1764.

Caron, D.A., F.R. Pick, and **D.R.S. Lean**. 1985. Chroococcoid cyanobacteria in Lake Ontario: vertical and seasonal distributions during 1982. *J. Phycol.*, 21: 171–175.

**Charlton, M.N.** 1985. Lake Erie oxygen revisited. NWRI Contribution No. 85–37. Submitted to *J. Great Lakes Res.*

**Charlton, M.N.** Organic material sedimentation rates in Lake Erie, 1979. Submitted to *J. Great Lakes Res.* In press.

**Dobson, H.F.H.** 1984. Lake Ontario Water Chemistry Atlas. Environment Canada, Inland Waters Directorate, Ottawa, Sci. Ser. No. 139, 59 pp.

El-Shaarawi, A.H., and **S.R. Esterby**. 1984. Statistical analyses of Niagara River data for the Niagara River Toxics Committee report. NWRI Contribution No. 84–37.

El-Shaarawi, A.H., **S.R. Esterby**, N.D. Warry, and K.W. Kuntz. 1985. Evidence of contaminant loading to Lake Ontario from the Niagara River. *Can. J. Fish. Aquatic Sci.*, 42(7): 1278–1289.

**Esterby, S.R.** 1985. Statistical methods for studying biotic responses to persistent toxic substances. NWRI Contribution No. 85–106.

**Esterby, S.R.** 1985. A program for estimating the point of change and degree in polynomial regression. Environment Canada, Inland Waters Directorate, Burlington, Ontario, Sci. Ser. No. 147, 13 pp.

**Esterby, S.R.**, and A.H. El-Shaarawi. 1984. Coliform concentration in Lake Erie — 1966 to 1970. *Hydrobiologia*, 111: 133–146.

**Esterby, S.R., L.D. Delorme**, H. Duthie, and **N.S. Harper**. 1985. Analysis of multiple depth profiles in sediment cores: An application to pollen and diatom data. *Hydrobiologia*. In press.

**Glooschenko, W.A.** 1986. Monitoring the atmospheric deposition of metals by use of bog vegetation and peat profile. *Adv. Environ. Sci. Technol.*, 17: 507–533.

**Glooschenko, W.A., R.A. Bourbonniere**, and W. Shoty. 1985. Environmental impact of peat harvesting and combustion upon aquatic ecosystems. Symposium 85 — A Technical and Scientific Conference on Peat and Peatlands, NWRI Contribution No. 85–100. In press.

**Glooschenko, W.A., L. Holloway**, and N. Arafat. 1986. The use of mires in monitoring the atmospheric deposition of heavy metals. *Aquatic Botany*. In press.

**Harper, N.S.** 1985. Palynology from Humboldt Lake (Core 111), Saskatchewan. Tech. Note AED-85-4, NWRI, Burlington, Ontario, 20 pp.

**Holloway, L.**, and **L.D. Delorme**. 1985. Specific gravity determinations of sediments from Humboldt Lake (Core 111) and Lonetree Lake (Core 115), Saskatchewan. Tech. Note AED-85-6, Burlington, Ontario, 21 pp.

**Holloway, L.**, and **L.D. Delorme**. 1985. Specific gravity determinations of sediments from Saskatchewan Lake cores (108, 109, 118, 120). Tech. Note AED-85-1, NWRI, Burlington, Ontario, 12 pp.

**Holloway, L.**, and **L.D. Delorme**. 1985. Specific gravity determinations of sediments from Alberta Lake cores (110, 112, 113, 114, 116, 117). Tech. Note No. 2, AED-85-2, NWRI, Burlington, Ontario, 17 pp.

**Leppard, G.G.** 1984. The ultrastructure of lacustrine sedimenting materials in the colloidal size range. *Arch. Hydrobiol.*, 101: 521–530.

**Leppard, G.G.** 1984. Organic coatings on suspended particles in lake water. *Arch. Hydrobiol.*, 102: 265–269.

**Leppard, G.G.** 1984. Relationships between fibrils, colloids, chemical speciation and the bioavailability of trace heavy metals in surface waters — a review. NWRI Contribution No. 84–45.

**Leppard, G.G.** 1985. Transmission electron microscopy applied to water fractionation studies — a new look at DOC. *Water Pollut. Res. J. Can.*, 20(2): 100–110.

**Leppard, G.G., J. Buffle**, and R. Baudat. 1985. A description of the aggregation properties of aquatic pedogenic fulvic acids — combining physicochemical data and microscopical observations. *Water Res.* In press.

**Manning, P.G., T. Birchall**, and W. Jones. 1984. The partitioning of nonapatite inorganic phosphorus in sediments from Lakes Erie and Ontario. *Can. Mineral.*, 22: 357–365.

- Manning, P.G.**, K.R. Lum, **H.K.T. Wong**, and T. Birchall. 1985. Origin and age of the ferrihydrite layer in Lake Ontario sediments. *Can. Mineral.* 23: 103–110.
- Martini, J.P., and **W.A. Glooschenko**. 1985. Cold climate peat formation in Canada and its relevance to Lower Permian coal measures of Australia. *Earth-Sci. Rev.*, 22: 107–140.
- Mathias, J.A., and **J. Barica**. 1985. Gas supersaturation as a cause of early spring mortality of stocked trout. *Can. J. Fish. Aquat. Sci.*, 42: 268–279.
- Mayer, T.** 1984. Phosphorus mobility in sediments upon lake acidification. NWRI Contribution No. 84–44.
- Mayer, T.** 1985. A review of procedures for evaluation of bioavailable phosphorus in particulate materials. NWRI Contribution No. 85–105
- Mayer, T.**, and J.R. Kramer. 1985. Effect of lake acidification on the uptake of phosphorus by sediments. NWRI Contribution No. 85–104. Submitted to *Water, Air and Soil Pollution*.
- McQueen, D.J., **D.R.S. Lean**, and M.N. Charlton. Iron-phosphorus interactions in anoxic and aerated hypolimnetic water. *Water Res.* In press.
- Murphy, T.P.**, K.J. Hall, K.I. Ashley, A. Mudroch, M. Mawhinney, and H. Fricker. 1985. In-lake precipitation of phosphorus by lime treatment. NWRI Contribution No. 85–167.
- Nagy, E., and **D.S. Painter**. 1985. Season variations of 2,4-D in Buckhorn Lake. *Water Pollut. Res. J. Can.*, 20(1): 106–116.
- Nriagu, J.O.** 1985. Cupellation: The oldest quantitative chemical process. *J. Chem. Educ.*, 62: 668–674.
- Nriagu, J.O.** 1985. Lead contamination of the Canadian environment. In *Proc. Health Effects Workshop, Commission on Lead in the Environment*, Royal Society of Canada. In press.
- Nriagu, J.O.** 1985. Historical perspective on the contamination of food and water with lead. In *Dietary and Environmental Lead*, K.R. Mahaffey (ed.), Elsevier, Amsterdam, pp. 1–41.
- Nriagu, J.O.**, and Y.K. Soon. 1985. Distribution and isotopic composition of sulphur in sediments of northern Ontario. *Geochim. Cosmochim. Acta*, 49: 823–834.
- Oliver, B.G., and **R.A. Bourbonniere**. 1985. Chlorinated contaminants in surficial sediments of Lakes Huron, St. Clair and Erie: implications regarding sources along the St. Clair and Detroit rivers. *J. Great Lakes Res.*, 11: 366–372.
- Painter, D.S.**, and G. Kamaitis. 1985. Reduction of *Cladophora* biomass and tissue phosphorus in Lake Ontario, 1972–1983. NWRI Contribution No. 85–39.
- Painter, D.S.**, and J. Waltho. 1985. Short-term effect of harvesting on milfoil growth. NWRI Contribution No. 85–36. Submitted to *Proc. 1st Int. Symp. on Eurasian watermilfoil*.
- Rosa, F.** 1985. Sedimentation and sediment resuspension in Lake Ontario. *J. Great Lakes Res.*, 11(1): 13–25.
- Solomon, K.R., J.Y. Yoo, **D.R.S. Lean**, N.K. Kaushik, K.E. Day, and G.L. Stephenson. A study on the evaluation of the impact of Permethrin on aquatic communities. II. Permethrin dissipation. *Can. J. Fish. Aquat. Sci.* In press.
- Solomon, K.R., J.Y. Yoo, **D.R.S. Lean**, N.K. Kaushik, K.E. Day, and G.L. Stephenson. Methoxychlor distribution, dissipation and effects in freshwater limnocoarals. *Environ. Toxicol. Chem.* In press.
- Wong, H.K.T.**, and **J.O. Nriagu**. 1985. Particulate metal dynamics in lakes near the smelters at Sudbury, Ontario. In *Proc. of Trace Substances and Environmental Health*, Vol. 18, D.D. Hemphill (ed.), University of Missouri at Columbia, pp. 416–426.
- Wong, H.K.T.**, and **J.O. Nriagu**. 1985. Flux of particulate metals into a remote lake in Algonquin Park, Ontario. In *Proc. of Trace Substances and Environmental Health*, D.D. Hemphill (ed.). In press.



## AQUATIC PHYSICS AND SYSTEMS DIVISION

The Aquatic Physics and Systems Division conducts integrated and multidisciplinary research programs in general areas of physical limnology, environmental optics and remote sensing, environmental modelling and simulation and acidification of aquatic systems. The Division contributes to management of Canadian freshwater resources on two levels. First, it contributes to the fundamental understanding of physical processes and to the elucidation of interactions between components of aquatic systems. Secondly, through the application of models, the Division achieves an appropriate level of synthesis for identification and assessment of water management alternatives in complex aquatic systems. The Division provides support for Data Management, archiving and computer programming assistance for NWRI research programs and the WHO Collaborating Centre. These responsibilities are shared among four sections: Physical Limnology, Environmental Simulation, Environmental Optics, and Data Management.

### PHYSICAL LIMNOLOGY SECTION

The goals of the Physical Limnology program are to describe and quantify physical processes such as mean transport and turbulent mixing to assist the interpretation of biological and chemical experiments, surveillance measurements, and to provide input to water quality concerns involving the transport and dilution of contaminated effluents. To achieve these goals the Section collects field observations, analyzes and interprets data, and synthesizes results through theoretical and modelling studies. Most of the Section's work supports multidisciplinary NWRI programs. Other clients and collaborators are provincial agencies (Ontario Ministry of the Environment, Ontario Ministry of Natural Resources, Ontario Hydro), municipal authorities and consulting engineers.

**Lake Erie Studies.** Although the synthesis report of the 1979 and 1980 Lake Erie experiments has been delayed, and will now be a special issue of the *Journal of Great Lakes Research* in early 1986, further scientific progress has been made. A strong coupling between transient thermal structure and near inertial period currents has been demonstrated. This has been confirmed by analysis of data from the prototype profiling system GVAPS. A successful finite-element storm surge model, a first of its kind, has been developed and tested on the Lake Erie data set that includes data from deep water tide gauges. (Boyce, Hamblin)

**Lake Ontario Studies.** Analysis of the 1982–83 circulation experiment in Lake Ontario culminated in a major report by Simons and Schertzer and a series of papers. The persistent flow eastward along the south shore of the lake and the counterbalancing westward flow mid-lake can be related to the distribution of contaminants in the sediments of Lake Ontario.

Concern with respect to the juxtaposition of outfalls and drinking water intakes along the densely populated and heavily industrialized north shore of Lake Ontario prompted a multidisciplinary field program in 1984. The physical study, with its

array of thermistor strings extending from Hamilton to Cobourg, emphasized the alongshore development of flow episodes where previous studies had emphasized the cross-sectional structure of the coastal boundary layer. Alongshore current speeds often exceed 20 km·day<sup>-1</sup>, and episodes between current reversals last from five to ten days; total alongshore displacement of water may exceed 100 km. (Simons)

**Niagara River Studies.** Field experiments continued in the Niagara River area through the 1984 and 1985 field season. Of particular note are the long-term trajectories obtained by satellite-tracked drifters, an example of which is shown in Figure 9. The satellite drifter program has been operated in close participation with the Great Lakes Environmental Research Laboratory (U.S. National Oceanic and Atmospheric Administration [NOAA]) in Ann Arbor, Michigan. These studies were carried out in support of the toxic contaminants surveys undertaken by the Environmental Contaminants Division. (Murthy)

**Lake St. Clair Experiments.** The physical program was undertaken in support of the Upper Great Lakes Connecting Channels Study and focussed on Lake St. Clair. It was coordinated with programs developed at the U.S. EPA laboratory in Grosse Ile and at the NOAA laboratory in Ann Arbor. Two goals were addressed. The first was to provide sufficient information on the distribution of horizontal currents in the lake to verify a numerical circulation model. The second was to study the transport of suspended material through the lake, recognizing the importance of this material as a compartment for organic contaminants. The bulk of the current meter information was collected with Neil Brown vector averaging acoustic current meters (model SACM). This is the first time we have deployed these instruments and we have been encouraged by the excellent return of data (>90%). A mid-lake tower was installed and instrumented to serve as the focal point of an intensive sediment resuspension experiment conducted during September and October 1985. (Bull)

**Yukon River Headwater Lakes Study.** A series of under-ice temperature profiles in the outflow regions of several Yukon River headwater lakes resulted in more detailed knowledge of the outflow dynamics of lakes and an estimate of the heat transfer coefficient between ice and water. This information is essential to the modelling of ice-covered lakes. (Hamblin)

### ENVIRONMENTAL SIMULATION SECTION

The main objective of the Environmental Simulation Section is to develop and maintain a modelling capability for the integration of research results and data from the various disciplines of water sciences. This is achieved by developing a general modelling framework that can be readily adapted to address a wide range of environmental problems such as lake eutrophication, toxic contamination and watershed acidification. The purpose of the models is threefold: to make predictions and provide guidelines and trend analysis for

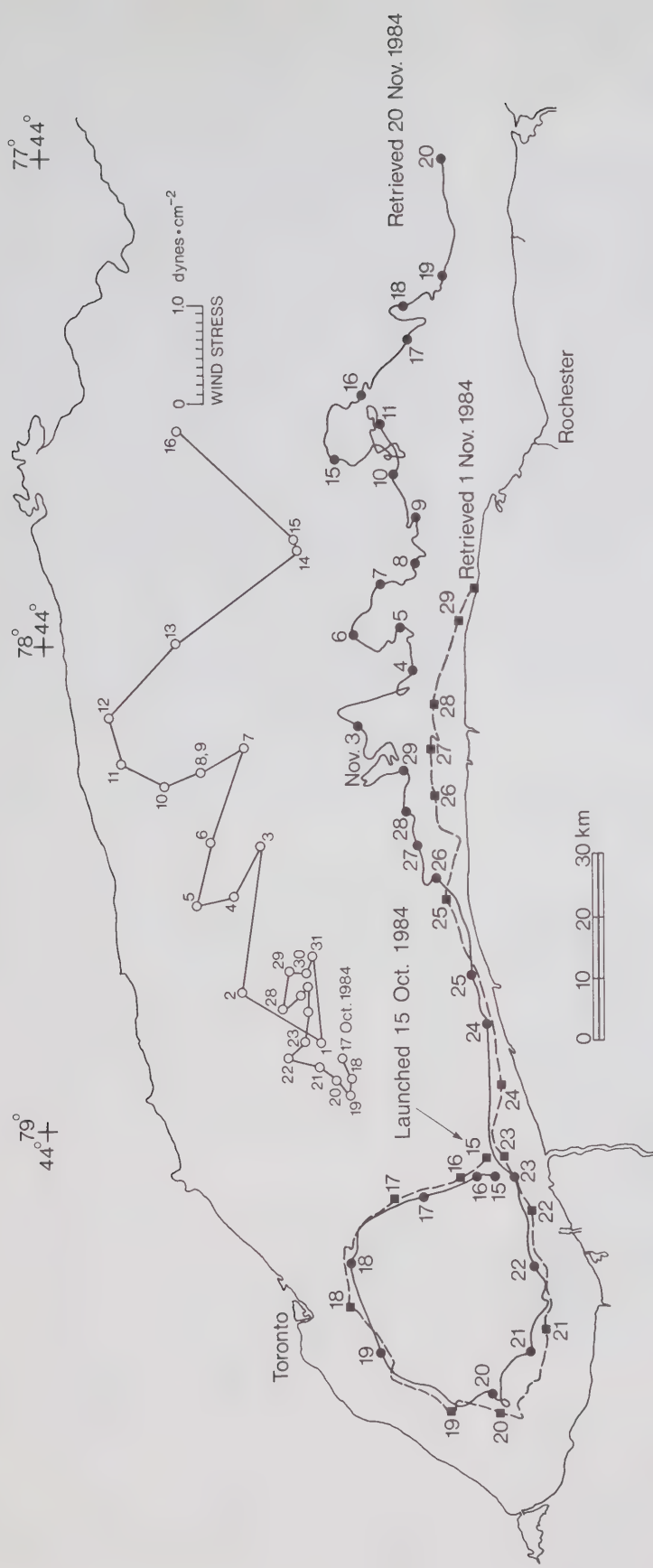


Figure 9. Lagrangian drifter experiment to track Niagara River plume, October 15 to November 20, 1984.

environmental management problems; to provide feedback to ongoing research and monitoring programs on the gaps of knowledge; and to maintain a strong focus of systems modelling expertise in the Aquatic Physics and Systems Division and consolidate modelling efforts by close collaboration with other divisions.

**St. Clair River Contaminant Model.** The St. Clair River system connects Lake Huron with Lake Erie. A large number of industries are located along its shores to utilize the large amount of water flowing through the system (about 6000 m<sup>3</sup>·s<sup>-1</sup>). Toxic contaminants in the river water and in the bottom sediments are the result of the industrial development along the river and lake shores. To assess the hazard or potential hazard of the chemicals, mathematical modelling and simulation techniques can be used to quantify and predict the concentrations of the chemicals in various parts of the system, such as Lake St. Clair. The computer model integrates information on the chemical properties with the environmental properties to produce reliable predictions of the fate of the toxic contaminants found in the system. The mathematical model TOXFATE, previously used to predict the fate of toxic contaminants entering Lake Ontario from the Niagara River, is being adapted to simulate the environmental conditions in the St. Clair River system. TOXFATE is being coupled with a hydrodynamic model of Lake St. Clair to predict the spatial distribution pattern of toxic contaminants and nutrients in the water and in the bottom sediments. Results of the simulations are displayed using personal computers such as the Commodore 64 or the IBM PC; Figure 10 shows an example of such an interactive display. (*Halfon, Simons*)

**Niagara River Contaminant Loading.** There are two hypotheses regarding the pollution concentration distribution along the Niagara River. One is that the concentration of pollutants is the same throughout the length of the river. The other is that the concentration is generally higher in the downstream portion. Statistical methods and the complete-linkage clustering analysis have been used to test these hypotheses. This method has been applied to the observed data of chlorinated organics and heavy metals collected from large-volume water samples and in suspended sediments at five stations (Fig. 11): Fort Erie (FE), Chippawa (C), Wheatfield (W), Queenston (Q) and Niagara-on-the-Lake (NOTL), with one or two samples per station once during May, July and October–November of 1981, respectively. The general results show that concentrations at NOTL and Q are similar to each other but are different from the concentrations at other locations. The locations FE, C and W always form a group.

More specifically, it is found that out of the 30 chemicals, 16 show a significant increase in concentration in the downstream direction, 8 do not show such a trend, and the remaining 6 are below detection level. (*El-Shaarawi*)

**Watershed Acidification Model.** A watershed acidification model has been developed to investigate the impact of acidic deposition on Canadian watersheds. The model considers the sulphate ions as mobile entities that follow the complicated water pathways through the snowpack, the surface soil layers, ground water, streams and lakes. Depending on the duration and the nature of the soil and water contact, these ions can cause major disruptions to the chemical balances in the aquatic regimes.

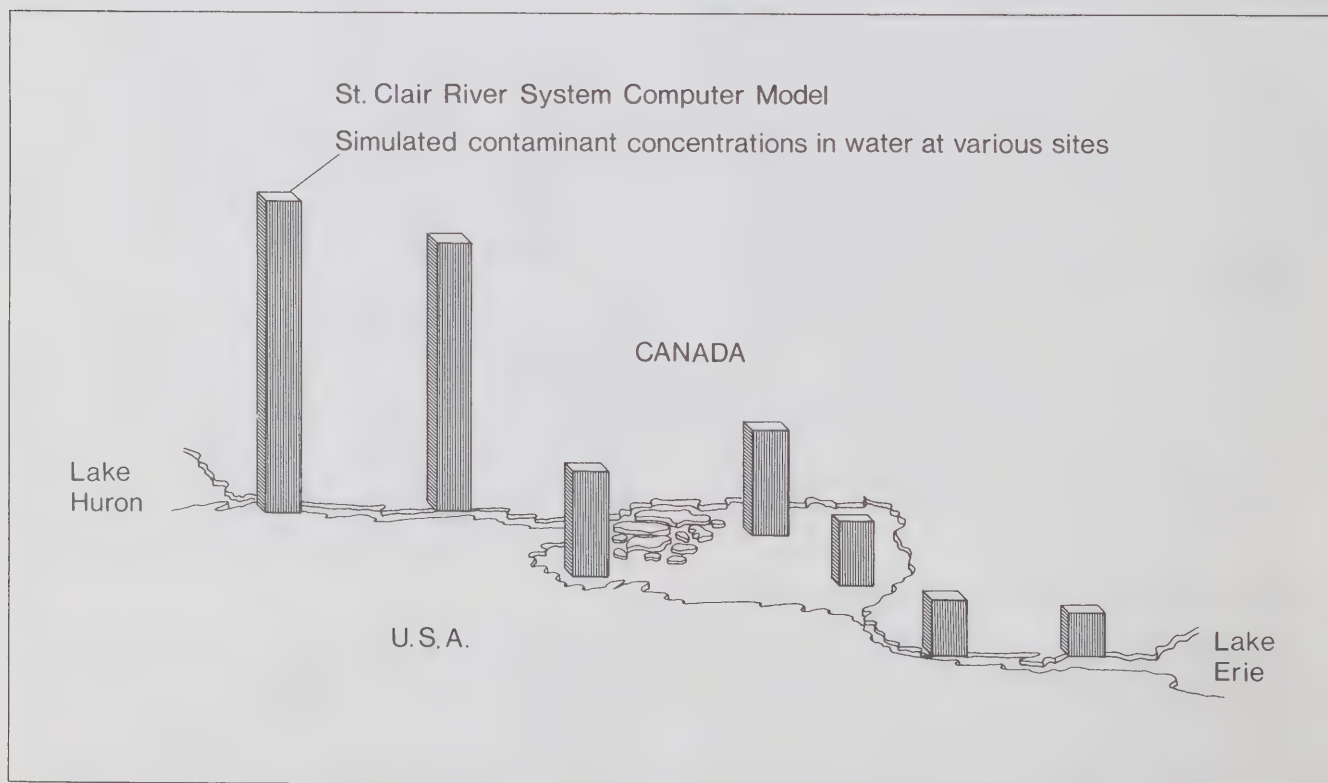


Figure 10. Example of interactive display originated with an IBM PC with the model TOXFATE. The St. Clair River system is located between Lakes Huron and Erie. Sarnia and Detroit are cities located on its shores.



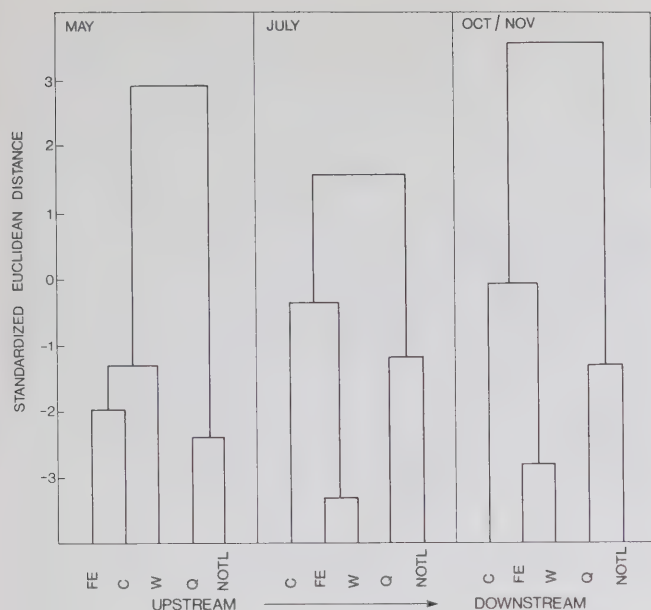


Figure 11. Complete linkage clustering using the standardized Euclidean distance for Water Quality Branch aqueous phase data.

Although most of the variations are due to hydrological events, the depression of pH, which signifies an increase in acidity, during the early springtime, is particularly related to snowmelt episodes. Through a series of model calibration and verification with data from several Canadian watersheds in collaboration with other agencies, we are able to test the general applicability of this model as a research tool for examining detailed impacts of acidic deposition on aquatic regimes. (Lam, Bobba)

**Excess Sulphate Yields of Rivers in Nova Scotia and Newfoundland.** River yields of excess sulphate are often calculated as mean discharge-weighted excess sulphate times mean annual runoff, and the reliability of this method of calculation increases with an increase in the number of samples available. For this reason, data are usually grouped over several years. The data are plotted on Figure 12 for 12 river stations in Nova Scotia; the plot shows a marked decrease, by nearly half, in the river yields of excess sulphate between 1971 and 1973 and 1982 and 1984. A similar comparison (not shown) was made for eight rivers in Newfoundland, and a similar marked decrease in excess sulphate yields was observed.

If the amount of sulphate carried by these rivers has decreased by nearly half, and there is no great change in the cation denudation rates (CDR) of these rivers, then it is reasonable to expect that the mean pH values of these rivers will have increased. It has been found that this relationship holds for the rivers with softer water in Newfoundland. The rivers with the softest water show the largest increases in mean discharge-weighted pH, whereas the pH changes of the two rivers with the hardest water are statistically insignificant.

The case is not so simple for the soft water rivers of Nova Scotia, the pHs of which are dominated to a much greater extent by the presence of organic acids than those in Newfoundland. In Nova Scotia, the greatest increases in pH are seen for the slightly harder river waters with somewhat lower mean DOC. This shows that for rivers in whose watersheds the natural acidification processes have not proceeded too far, a

decrease in sulphate deposition will mean an improvement in river water quality, but not enough is yet known about the natural acidification process in the very soft water river watersheds. Some of these results are used for improvement of the CDR model developed in the Environmental Simulation Section. (Thompson, Fraser)

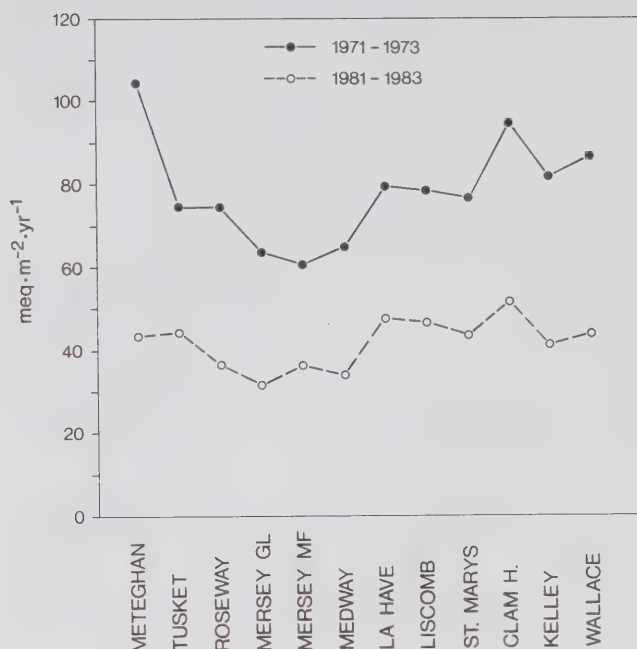


Figure 12. Excess sulphate yields ( $\text{meq} \cdot \text{m}^{-2} \cdot \text{yr}^{-1}$ ) of Nova Scotia rivers. GL — George Lake; MF — Mill Falls; H — Harbour.

**Climate Models.** Contributions to the Canada Climate Program have been oriented toward improved understanding and computer simulation of (a) the seasonal and annual energy balance at the air-water interface and (b) the seasonal variations of thermal structure and stratification of lakes and the upper layers of the ocean.

Goals in the first year of study included improving the physical data base and updating numerical models for computing long-term variations of the energy balance at the air-water interface for Lake Erie and Lake Ontario. Climatological data bases for synoptic observations have been compiled from 1950 to 1983 for both lakes. Numerical model development, climatological analyses of the data, and derivation of the long-term energy balance for each lake have been completed. Figure 13 shows verification results for the major components of the Lake Ontario energy balance, i.e., net radiation ( $Q^*$ ), latent heat flux ( $Q_E$ ), conductive heat flux ( $Q_H$ ), the surface heat flux ( $Q_T$ ) and evaporation indicating high reliability of the model output. (Simons, Schertzer)

**Hydrodynamic Model.** For coastal currents, a combination of spectral techniques, hydrodynamic models and empirical procedures proved conclusively that observed current fluctuations cannot be explained by either a balance of local wind and bottom stress or by free topographic waves but that both processes contribute equally. Semi-empirical transfer function models based on the concept of resonant topographic wave

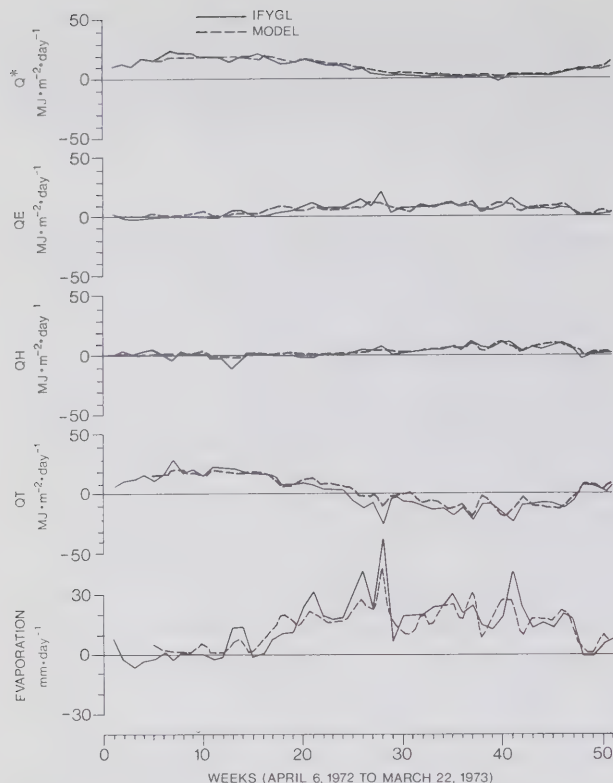


Figure 13. Verification of Lake Ontario energy balance model. IFYGL — International Field Year Great Lakes.

response to wind forcing in the presence of bottom friction were developed and found to explain 70% to 80% of the observed coastal current variations.

With respect to open lake circulation, it was shown that none of the models available in the pertinent literature was suitable to estimate seasonal-mean circulations. It was found that the mean circulation observed during the 1982/83 Lake Ontario field study could only be reproduced by high-resolution non-linear models. To evaluate whether this result was applicable in general, circulations were computed for 12 years of climatological winds. For all years, the circulations obtained from the new model deviated from those computed by conventional models in the same manner. (Simons)

**Technology Transfer.** The Environmental Simulation Section continued to provide mathematical models to government and other users. For example, at the request of PAHO (Pan American Health Organization), a study was undertaken to evaluate the effects of a planned outflow diversion from Lake Chapala in Mexico to improve the water supply to the city of Guadalajara. An operational model for predicting the movement and dispersion of accidental radioactive spills along the north shore of Lake Ontario was developed for the Ontario Ministry of the Environment. The model was based on many years of data collection and modelling studies on Lake Ontario and then adapted for use on microcomputers.

In response to continuing requests for the use of these models and assistance in their application, three of the most frequently requested models were documented in great detail. These models are (1) a single-layer circulation/storm surge model, (2) a multi-level model for computing circulations and temperature changes, and (3) a pollutant transport model. (Simons, Lam)

## ENVIRONMENTAL OPTICS SECTION

The principal goal of the Environmental Optics Section is to conduct and apply directly both experimental and theoretical research related to the optical properties of the aquatic environment. The techniques of spectro-optical physics and radiative transfer theory are utilized, in conjunction with directly acquired *in situ* optical data or remotely acquired airborne and/or satellite multispectral optical data, to develop interpretive and predictive optical models and methodologies, and subsequently to apply these models and methodologies to water resource issues and concerns.

The optical physics activity comprises a basic long-term research program together with short-term studies which attempt to comply with specific problems as occasions and circumstances dictate. During the past year, the Section's effort was largely devoted to the Great Lakes region of central Canada. Specific activities included the following:

- A study of pertinent available LANDSAT imagery over the Lake Huron/Lake St. Clair/Lake Erie sediment transport system. The separation of these transport avenues into well-defined independent zones that retain their independent identities over substantial distances throughout the interconnecting channels is clearly evident. Further analyses of these transport phenomena are planned for the coming year. (Bukata)
- Generation of an optical atlas describing the Great Lakes in terms of *in situ* optical data collected by the Section during the time interval 1973–1983. Included in this atlas are such optical features and parameters as surface transmission contours; summer photic depths; transmission transects; relationships among beam attenuation coefficients, irradiance attenuation coefficients, and Secchi disk depths; sighting range; and photosynthetic available radiation among others. The atlas illustrates these optical features in graphical, pictorial, and/or tabular form and intercompares these features for Lakes Erie, Ontario, Superior and Huron/Georgian Bay. It is available for distribution as an NWRI manuscript. (Bukata, Jerome, Bruton)
- Collection of remotely sensed data over Lake St. Clair utilizing the recently developed Shipborne Reflectance Radiometer System (SRRS) and the development of computer methodology to utilize these data to estimate suspended mineral concentrations. (Jerome, Bruton)
- A study of Great Lakes coastal wetland regions utilizing airborne data collected over such areas as Georgian Bay/North Channel and Lake St. Clair. These data were obtained during periods of both high and low water levels, and this project, which is being performed in collaboration with the Great Lakes Fisheries Research Board, attempts to relate the change in areal extent of marshlands to variations in water level. (Bruton, Bukata, Jerome)

## DATA MANAGEMENT SECTION

The Data Management Section provides data management support and EDP software development services to the organizations located at the Canada Centre for Inland Waters. The data archives of NWRI are maintained and managed for the support of the NWRI research and Inland Waters Directorate, Ontario Region operational programs. Consulting services are maintained to provide advice and guidance in such areas as data base usage, software problems, the use of software packages, microcomputer hardware/software selection, and the efficient use of the in-house CYBER 171 mainframe computer.



The Section provides the operational support for the United Nations Global Environmental Monitoring System (GEMS) data base and the Great Lakes Surveillance data base (STAR).

**Major Activities.** Software system design and development support was provided for 53 different studies of the various organizations located at CCIW.

A Treasury Board submission for new mainframe computer facilities at CCIW was done in conjunction with the Computer Services Section and the Systems and Informatics Directorate in Ottawa. This submission included program-related computer requirements, conversion and training requirements along with a "make versus buy" analysis of the various alternatives available to NWRI.

The automated laboratory data acquisition system (AWQUALABS) was completed and the development team disbanded. A total of 109 computer programs were written for this system to provide for data acquisition, analysis and laboratory management functions. The operational support for the system now rests with the National Water Quality Laboratory.

A new release of the System 2000 data base software was installed on the CYBER 171. All data base programs were recompiled to operate under the new version. This new version provides additional features which aid in the development and/or enhancement of the various data base systems that are operational on the CYBER.

Three issues of the Data Management and Computer Services newsletter (UPDATA) were distributed. The distribution of the newsletter is for CYBER users, micro users, study leaders, management personnel and other interested staff. The purposes of UPDATA are to provide a vehicle to exchange information, to improve the awareness of various computer-related topics, and to provide for increased productivity in the use of the CYBER 171. Some topics covered in the newsletter are new general-purpose software, new developments in communications, problems encountered by users, featured applications, hardware, microcomputer links, word processing, and a novice user corner.

Communication links between the CYBER and the Wang OIS system and the CYBER and the MICOM 2001 system were established to aid the integration of text files for document production. In conjunction with the Environmental Protection Service, facilities were established to translate documents from one word processing format to another. Currently, Wordstar to MICOM and MICOM to Wang translations are possible. In future, additional software to translate other formats will be obtained as the need arises.

Data archiving support was provided for the Great Lakes Surveillance, Solar Radiation, Meteorological, GEMS and LRTAP programs. This support consisted of data entry, data documentation, data base updating, software enhancement, data archiving and data retrieval functions.

Input was provided to an international review meeting of the GEMS/WATER program. As a result of the review, a "GEMS/WATER Data Evaluation Report" was produced by the World Health Organization (WHO) in Geneva. The review has led to the redesign of the data input form to reflect more accurately the chemical parameters required for each type of water (lake, river and ground water) sampled. Other changes to the program have been identified and will take place over the next few years. A complete set of data listings and statistical summaries for the 1982-1984 data was produced and forwarded to WHO, Geneva, for distribution to the various regional centres and countries (60) involved in the program. The 1979 to 1981 data were microfiched and distributed to all participants in the program.

All Applied Physics and Systems Division staff publications have been catalogued and the requirements for reprints are being met as they arise.

Introductory and advanced CYBER computer courses as well as a course on the CALCOMP plotter were given to approximately 60 users.

A procurement data base system was developed for the Staff Services Division. This system provides for the partial automation of the procurement function, along with the ability to produce reports to aid the management of the procurement process.

## STAFF LIST

**Chief — E. Ongley, B.A., Ph.D.**

**Secretary — S. Tapping**

**A/Administrative Officer — J. Major**

### Physical Limnology

#### Head

**F.M. Boyce, B.A.Sc.,  
M.Sc.**

physical limnology

#### Researchers

J. Bull, B.A.Sc.

physical limnology

F. Chiocchio, P.Eng.

physical limnology

P. Hamblin, B.Sc., M.Sc.,  
Ph.D.

physical limnology

M. Kerman

physical limnology

K. Miners, B.A.

coastal zone research

C.R. Murthy, B.E.,  
M.E., Ph.D.

physical limnology

D. Robertson, B.Sc.

physical limnology

### Environmental Optics

#### Head

**R.P. Bukata, B.Sc., M.Sc.,  
Ph.D.**

lake optics and satellite  
studies

#### Researchers

J.E. Bruton, B.Sc.

lake optics remote sensing

J. Jerome, B.Eng.

lake optics remote sensing

### Environmental Simulation

#### Head

**D. Lam, B.Sc., Ph.D.**

contaminant transport  
modelling

#### Researchers

A.G. Bobba, B.Sc.,  
M. Tech., M.Sc.

hydrogeology and  
contaminant modelling

A. El-Shaarawi, B.Sc.,  
M.Sc., Ph.D.

statistical modelling

A. Fraser, B.Sc.

water quality and LRTAP  
modelling

E. Halfon, Ph.D.

toxic substance modelling

W. Schertzer, B.A., M.Sc.

water quality and climate  
modelling

T. Simons, M.Sc., Ph.D.

hydrodynamic modelling

M.E. Thompson, B.A.,  
M.A. Ph.D.

aquatic effects of LRTAP



## Data Management Section

### A/Head

R. Duffield, B.Sc., M.B.A. data management services

## Computer Applications

S. Beal microcomputer applications  
H. Comba, B.Sc. data base administration  
J. Dowell, B.Math software development  
B. Hanson, B.A.(Hon), software development  
M.B.C.S.  
J. Hodson, B.Sc. software development  
A. Liu, M.Sc. software development  
K. Miles software development  
B. Ventresca, B.A.(Hon), software development  
B.Sc.  
A. Zingaro, B.Sc. software development

## Data Processing and Archiving

J. Byron data processing and  
archiving  
J. McAvella data processing and  
archiving  
W. Nagel data processing and  
archiving

## COMMITTEE MEMBERSHIP

### A.G. Bobba

Member, Modelling Panel, American Institute of  
Hydrology  
Inland Waters Directorate Hydrologic Research  
Program Committee

### F.M. Boyce

Secretary, Scientific Committee, CMOS,  
1983–1986  
Board Member, IAGLR 1983–1986  
Rapporteur, Oceanography, *Canadian  
Geophysical Bulletin*

### R. Duffield

Inland Waters Directorate Information Technology  
Committee

### A.H. El-Shaarawi

Member, International Statistical Institute  
Ph.D. Candidate Supervisory Committee,  
Department of Mathematical Science, McMaster  
University

### E. Halfon

Vice President, International Society of Ecological  
Modelling, North American Chapter  
Editorial Board, *International Journal of Ecological  
Modelling*

### P.F. Hamblin

Associate Editor, *Physical Limnology Journal of  
Great Lakes Research*

Ph.D. Candidate Supervisory Committee,  
Department of Civil Engineering, McMaster  
University

International Association for Great Lakes  
Research, Membership Committee

Mesoscale Subcommittee, CMOS, 1985–1986

### D.C.L. Lam

Editorial Board, *International Journal of Advances  
in Water Resources*

IAEA Working Group on Coastal Modelling

IJC Great Lakes Modelling Task Force

LRTAP National Assessment Task Force, Aquatic  
Effects

Ph.D. Candidate Supervisory Committee,  
Department of Civil Engineering, McMaster  
University

### E. Ongley

Western and Northern Regional Management  
Team

Western and Northern Regional Pesticides  
Committee

Mackenzie River Interdepartmental Working Group

Executive Committee, National Association for  
Sediment Water Science

Organizing Committee, International Association  
of Hydrological Sciences — 1987 Vancouver  
Assembly

Canadian Committee for SCOPE

NWRI–Water Quality Branch Working Group on  
Monitoring (Chairman)

### W.M. Schertzer

Inland Waters Directorate Hydrologic Research  
Program Committee

Ontario Regional Climate Advisory Committee

### M.E. Thompson

Associate Editor, *Hydrological Sciences Journal*

## PUBLICATIONS

Anderson, J.E., A.H. El-Shaarawi, S.R. Esterby, and T.E. Unny. 1984. Dissolved oxygen concentrations in Lake Erie (U.S.A.–Canada). 1. Study of spatial and temporal variability using cluster and regression analysis. *J. Hydrol.*, 72: 209–229.

Balakrishnan, N., M.L. Tiku, and A.H. El-Shaarawi. 1985. Robust univariate two-way classification. *Biomed. J.*, 27, N2: 123–138.

Beghelli, S., R. Guidorzi, E. Halfon, and F. Terragni. 1982. Identification of phosphorus dynamics in Kootenay Lake, Canada. *Ecol. Modelling*, 17: 11–32.

Bobba, A.G., and D.C.L. Lam. 1984. Application of linearly distributed surface runoff model for watershed acidification. *Proc. Canadian Hydrology Symposium*, Laval University, Quebec City. In press.

Bobba, A.G., D.C.L. Lam, D.S. Jeffries, D. Bottomley, J.Y. Charette, P.J. Dillon, and L. Logan. 1985. Modelling the hydrochemical regimes in acidified watersheds. Submitted to *J. Water Air Soil Pollut.*

Boyce, F.M. 1985. Lakes in Canada. In *The New Canadian Encyclopedia*, M. Hurtig Publishing Co., Edmonton, Canada.

Bukata, R.P., and A.G. Bobba. 1984. Determination of diffusion coefficients associated with the transport of 210 Pb radionuclides in lake bed sediments. *Geol.*, 5: 133–141.

- Bukata, R.P., J.E. Bruton, and J.H. Jerome.** 1984. Application of direct measurements of optical parameters to the estimation of lake water quality indicators. NWRI unpub. rep., 110 pp.
- Bukata, R.P., J.E. Bruton, and J.H. Jerome.** 1985. Application of direct optical parameters to the estimation of lake water quality indicators. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 140.
- Bukata, J.H., J.H. Jerome, and J.E. Bruton.** 1985. Direct optical measurements of the Laurentian Great Lakes. Part II. An optical atlas. NWRI unpub. rep., 170 pp.
- Dutka, B.J., K. Walsh, P. Ewan, A.H. El-Shaarawi, and R.S. Tobin.** 1984. Incidence of *Legionella* organisms in selected Ontario (Canada) cities. Sci. Total Environ., 39: 237–249.
- Elliott, J.R., A.H. El-Shaarawi, and D.R. Perison.** 1985. Association of chlorophyll *a* with physical and chemical factors in Lake Ontario, 1967–1981. Accepted for publication in the Proc. of the Workshop on the Statistical Aspects of Water Quality Monitoring.
- El-Shaarawi, A.H.** 1984. Dissolved oxygen concentrations in Lake Erie (U.S.A.–Canada). 2. A statistical model for dissolved oxygen in the Central Basin of Lake Erie. J. Hydrol., 72: 231–243.
- El-Shaarawi, A.H.** 1984. Statistical assessment of the Great Lakes Surveillance Program, 1966–1981, Lake Erie. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 136, 273 pp.
- El-Shaarawi, A.H.** 1985. Some goodness of fit methods for the Poisson-plus-added zeros distribution. Appl. Environ. Microbiol., 49(55): 1304–1306.
- El-Shaarawi, A.H.** 1985. Statistical aspects of setting a sampling strategy. Accepted for publication in J. français d'hydrologie.
- El-Shaarawi, A.H., and S.R. Esterby.** 1984. Statistical analysis of Niagara River data for the NRTC report. NWRI Contribution No. 84-37.
- El-Shaarawi, A.H., and M. Munawar.** 1985. The association of chlorophyll *a* and phytoplankton biomass in Lake Huron and Georgian Bay. Accepted for publication in Hydrobiologia.
- El-Shaarawi, A.H., and M.A. Neilson.** 1984. Changes in nutrient levels of lake water stored at 4°C. Can. J. Fish. Aquatic Sci., 41(6): 985–988.
- El-Shaarawi, A.H., and M.L. Tiku.** 1985. Regression analysis for censored data. Accepted for publication in the Proc. of the Workshop on the Statistical Aspects of Water Quality Monitoring.
- El-Shaarawi, A.H., J.C. Block, and A. Maul.** 1985. The use of historical data for estimating the number of samples required for monitoring drinking water. Sci. Total Environ., 42: 289–303.
- El-Shaarawi, A.H., S.R. Esterby, N.D. Warry, and K.W. Kuntz.** 1985. Evidence of contaminant loading to Lake Ontario from the Niagara River. J. Fish. Aquatic Sci., 42(7): 1278–1289.
- El-Shaarawi, A.H., K.W. Kuntz, and A. Sylvestre.** 1985. Estimation of loading by numerical integration. Accepted for publication in the Proc. of the Workshop on the Statistical Aspects of Water Quality Monitoring.
- Esterby, S.R., and A.H. El-Shaarawi.** 1984. Coliform concentrations in Lake Erie — 1966 to 1970. Hydrobiologia, VIII, pp. 133–146.
- Fraser, A.S.** 1985. Aquatic characterization for resources at risk in eastern Canada. Proc. Int. Symp. on Acid Precipitation. In press.
- Fraser, A.S.** 1985. Lake Erie point source loads. J. Great Lakes Res. Lake Erie Spec. Vol., Int. Assoc. Great Lakes Res.
- Halfon, E.** 1983. Is there a best model structure? I. Modelling the fate of a toxic substance in a lake. Ecol. Modelling, 20: 135–152.
- Halfon, E.** 1983. Is there a best model structure? II. Comparing model structures of different fate models. Ecol. Modelling, 20: 153–163.
- Halfon, E.** 1984. Error analysis and simulation of mirex behaviour in Lake Ontario. Ecol. Modelling, 22: 213–252.
- Halfon, E.** 1984. The composition of particulate matter in the euphotic zone of Lake Superior. J. Great Lakes Res., 10: 299–306.
- Halfon, E.** 1984. Is there a best model structure? III. Testing the Goodness of Fit. Ecol. Modelling, 27: 15–23.
- Halfon, E.** 1985. Modelling the fate of mirex and lindane off the Niagara River mouth. Ecol. Modelling. In press.
- Halfon, E.** 1985. The regression method in ecotoxicology: A better formulation using the geometric mean functional regression. Environ. Sci. Technol., 19: 747–749.
- Halfon, E.** 1985. The bootstrap and the jackknife in ecotoxicology or non-parametric estimates of standard error. Chemosphere, 14: 1433–1440.
- Halfon, E., and A.S. Fraser.** 1985. A fate model of toxic substances in Lake Ontario. J. Great Lakes Res. In press.
- Hamblin, P.F.** Yukon River Headwater Lakes Study 1983–1985: Preliminary Analysis and Data Report. NWRI unpub. rep.
- Hamblin, P.** 1985. Review of Storm surges — meteorological ocean tides (T.S. Murty). Can. J. Fish. Aquatic Sci., 42(12).
- Jerome, J.H., J.E. Bruton, and R.P. Bukata.** 1984. A short discussion on the intercomparison of transmissometers used at CCIW. NWRI unpub. rep., 17 pp.
- Jerome, J.H., R.P. Bukata, and J.E. Bruton.** 1984. Effect of solar zenith angle diurnal variation on estimation of primary production and irradiation. NWRI unpub. rep., 42 pp.
- Lam, D.C.L., and A.G. Bobba.** 1984. Application of linearly distributed surface runoff model for watershed acidification problems. Proc. Canadian Hydrology Symposium, Laval University, Quebec City, 11(13). In press.
- Lam, D.C.L., and A.G. Bobba.** Modelling watershed runoff and acidification. Hydrological and hydrochemical mechanisms and model approaches to the acidification of ecological systems. Irène Johansson (ed.), Nordic Hydrological Programme, NHP Rep. No. 10, pp. 205–215.
- Lam, D.C.L., A.G. Bobba, D.S. Jeffries, and J.M.R. Kelso.** Relationships of spatial gradients of primary production buffering capacity and hydrology in Turkey Lakes watershed. ASTM Technical Series, Philadelphia, Pa. In press.
- Lam, D.C.L., S. Boregowda, A.G. Bobba, D.S. Jeffries, and G.G. Patry.** Interfacing hydrological and hydrochemical models for simulating acidification effects in Canadian watersheds. Submitted to J. Water Air Soil Pollut.
- Marmush, Y.R., A.A. Smith, and P.F. Hamblin.** 1984. Pilot experiments on thermal bar in lock exchange flow. J. Energy Eng., ASCE, 110: 215–227.
- Maul, A., and A.H. El-Shaarawi.** 1984. Stratégies de prélèvement. Chapitre 9, Bactériologie des milieux aquatiques: Aspects écologiques et sanitaires, G. Martin (ed.), 2.2: 133–166.
- Maul, A., J.C. Block, and A.H. El-Shaarawi.** 1985. Statistical approach for comparison between methods of bacterial enumeration in drinking water (1985). J. Microbiol. Methods, 4: 67–77.
- Maul, A., M.A. Dollard, J.C. Block, J. Schwartzbrod, F. Hinzeln, and A.H. El-Shaarawi.** 1985. Contrôle de la qualité microbiologique de l'eau de distribution: Stratégie d'échantillonnage et identification des populations de micro-organismes. Rapport final. Université de Metz, France, 59 pp.
- Maul, A., A.H. El-Shaarawi, and J.C. Block.** 1985. Heterotrophic bacteria in water distribution systems. Part 1. Spatial and temporal variation. Sci. Total Environ., 44: 201–214.
- Maul, A., A.H. El-Shaarawi, and J.C. Block.** 1985. Heterotrophic bacteria in water distribution systems. Part 2. Sampling design. Sci. Total Environ., 44: 215–224.
- Maul, A., A.H. El-Shaarawi, and J.C. Block.** 1985. Modelling of bacterial populations and water quality monitoring in distribution systems. Accepted for publication in the Proc. of the Workshop on the Statistical Aspects of Water Quality Monitoring.
- Muir, L.R., and A.H. El-Shaarawi.** 1985. On the calculation of extreme wave heights: A review. Accepted for publication in Ocean Engineering.
- Murthy, C.R., and T.J. Simons.** 1984. Coastal currents in Lake Ontario during winter. NWRI Contribution No. 84-42.
- Murthy, C.R., T.J. Simons, and D.C.L. Lam.** 1985. Dynamic and transport modelling of the Niagara River plume in Lake Ontario. Proc. ICES, Nantes Symposium. In press.
- Murthy, C.R., T.J. Simons, D.C.L. Lam, and M. Walma.** 1985. Simulation of pollutant transport along the North Shore of Lake Ontario. NWRI Contribution No. 85-23.
- Murthy, C.R., D.C.L. Lam, T.J. Simons, J. Jedrasik, J. Miners, J.A. Bull, and W.M. Schertzer.** 1984. Dynamics of Niagara River plume in Lake Ontario. NWRI Contribution No. 84-7.
- Nielson, M.A., and A.H. El-Shaarawi.** 1984. Shipboard analysis of soluble nutrients in lake water versus analysis after storage. Environment Canada, Inland Waters Directorate, Tech. Bull. No. 133, 5 pp.
- Neilson, M., R. Stevens, and J. Hodson.** 1984. Documentation of the Averaging Lake Data by Regions (ALDAR) Program. Environment Canada, Inland Waters Directorate, Tech. Bull. No. 130.
- Ongley, E.D.** 1984. Regionalization of water quality in the upper Fraser River basin. British Columbia: Comment, Water Res., 18: 1059–1060.
- Ongley, E.D.** Considerations for network design for water quantity and quality surveys in Canada. Canadian Hydrology Symposium — 84, Proc. In press.
- Ongley, E.D.** Review of Gregory (ed.) Background to palaeohydrology: A perspective. Hydrol. Sci. J. In press.
- Ongley, E.D.** Detergent-phosphorus abatement: Point and nonpoint source basin response in southern Ontario. Environ. Geol. In press.



**Ongley, E.D.**, and D.P. Blachford. 1984. Tributary effects on mainstream suspended sediment chemistry. *Water Pollut. Res. J. of Can.*, 19(1): 37-46.

Patterson, J.C., and **P.F. Hamblin**. 1985. Thermal simulation of lakes with winter ice cover. NWRI Rep. No. 85-29.

Patterson, J.C., **P.F. Hamblin**, and J. Imberger. 1984. Classification and dynamic simulation of the vertical density structure of lakes. *Limnol. Oceanogr.*, 29(4): 845-861.

**Platford, R.F., A.G. Bobba**, and S.R. Joshi. 1984. The Port Granby radioactive waste management site. *Water Pollut. Res. J. Can.*, 19(2): 90-96.

**Robertson, D.G.** 1984. Report on data processing for DP/DX experiment at Cobourg on Lake Ontario.

**Schertzer, W.M.** 1985. Summary of water surface temperature observations for Lake Ontario (1966-1984) and Lake Erie (1967-1982). NWRI Contribution No. 85-159, 48 pp.

**Schertzer, W.M.**, and A. Sawchuk. 1985. Comparison of Toronto Island Airport winds for the period November to April 1973-1983. NWRI Contribution No. 85-158, 29 pp.

**Schertzer, W.M.**, and R. Stevens. 1984. Comparison of actual and simulated water quality responses to phosphorus loading scenarios in Lake Ontario and Lake Erie. NWRI Contribution No. 84-41, 24 pp.

**Simons, T.J.** 1984. Topographic response of nearshore current to wind: an empirical model. NWRI Contribution No. 84-17. *J. Phys. Oceanogr.*, 14: 1393-1398.

**Simons, T.J.** 1985. Temperatures and currents in Western Lake Ontario. June-November 1985. NWRI Contribution No. 85-158.

**Simons, T.J.** 1985. The mean circulation of unstratified water bodies. *J. Phys. Oceanogr.* 16 (to be published). NWRI Contribution No. 85-154.

**Simons, T.J.**, 1985. Effect of the outflow diversion on circulation and water quality of Lake Chapala. NWRI Contribution No. 85-22.

**Simons, T.J.** 1985. Reliability of circulation models. *J. Phys. Oceanogr.*, 15: 1191-1204. NWRI Contribution No. 85-46.

**Simons, T.J.**, and **C.R. Murthy**. 1984. Winter circulation in Lake Ontario. *J. Great Lakes Res.*, 11: 423-433

**Simons, T.J.**, and **W.M. Schertzer**. 1985. Stratification, currents and upwelling RPB in Lake Ontario, summer 1982. NWRI Contribution No. 85-152. *Can. J. Fish. Aquat. Sci.* (to be published).

**Simons, T.J.**, and **W.M. Schertzer**. 1985. The circulation of Lake Ontario during the summer of 1982 and the winter of 1982/83. NWRI Contribution No. 85-26.

**Thompson, M.E.** 1985. Cation denudation rates of rivers in Nova Scotia, 1971-1974 and 1977-1982. NWRI Contribution No. 85-28.

**Thompson, M.E.** 1985. The cation denudation rate model — its continuing validity. NWRI Contribution No. 85-30.

**Thompson, M.E.**, and Margo B. Hutton. 1985. Sulphate in lakes of eastern Canada: Calculated yields compared with measured wet and dry deposition. *Water Air Soil Pollut.*, 24: 77-83.

**Thompson, M.E.**, H.G. Thode, and **A.S. Fraser**. 1986. Sulphate yields and stable isotope ratios of sulphate sulphur in rivers of the Northwest Territories, Canada. *J. Appl. Geochem.* In press.



## ENVIRONMENTAL CONTAMINANTS DIVISION

The Environmental Contaminants Division investigates the pathways, fate and effects of five groupings of contaminants; organic chemicals, toxic metals, organometallics, radionuclides, and ions associated with acid rain. These investigations are conducted both the field and in the laboratory. Research information produced by the Division is valuable in substantiating recommendations for water management actions in polluted river basins. These actions may involve control of effluents, banning of chemicals, guidelines for consumption of biota or water, and many other procedures that can be implemented in Canada. These data may be valuable in negotiations on water quality matters, either interprovincially or internationally. Much of the published information is equally valuable as part of the total input required for toxic chemical assessments. Division activities are carried out in five sections as follows.

### ORGANICS-PATHWAYS SECTION

The objective of this Section is to resolve the entry, fate, distribution and transfer of organic contaminants in aquatic ecosystems. Research is conducted primarily at specified polluted aquatic ecosystems but also in the laboratory. Projects include studies in large and small river-lake systems. Atmospheric input of organic contaminants to the aquatic environment is also studied.

**Transport of Persistent Toxic Organic Chemicals in the Niagara River-Lake Ontario-St. Lawrence River Systems.** The use of chlorobenzenes as chemical markers in the determination of the fate of persistent organochlorine contaminants from the Niagara River in Lake Ontario was continued. Radio and satellite tracked drogues and improved large-scale water sampling and extraction methods were employed to extend greatly the area of the plume sampled. The results indicate that up to 50% of the higher molecular weight chlorobenzenes are deposited within 10 km of the river mouth on settling solids, but much of the remainder is transported out of the plume area in solution. Other organochlorine contaminants behaved in a similar fashion, with the more soluble compounds largely transported out of the Niagara River mouth area and significant amounts of the less soluble compounds being deposited on settling solids.

More recently, some of the concepts and techniques used in the Niagara River plume study have been employed in a new investigation of the transport of persistent organochlorine contaminants from Lake Ontario into the St. Lawrence River. Early emphasis in the study has been focussed on establishing the relative importance of different compartments such as water, suspended solids and suspended biomass. The possibility of distinctive contaminant patterns in the North Channel of the St. Lawrence River at Wolfe Island owing to industrial activity in the Bay of Quinte-Kingston areas is also under investigation. (Fox, Carey, Coletta)

**The Fate of 2,4-D in Freshwater Systems.** The focus of the 2,4-D studies was a concern for possible harmful effects of the use of the chemical in milfoil control both on freshwater biota and on water quality in such divergent areas as the Trent River system (Ontario) and the Okanagan Lakes (British Columbia).

Both pond and field studies were completed in 1984. The former, conducted in enclosed ponds, was considered a worst-case study, but showed only marginal toxic effects on fish fry and on clams during the first week after the chemical's introduction. Secondary effects were more noticeable and consisted of the collapsed milfoil beds providing an increased food supply to bacteria, clams and other bottom fauna.

A two-year study in Buckhorn Lake (of the Trent system) showed a wide distribution of the chemical in the whole lake during the herbicide application season (June and July). This was followed by rapid disappearance, then a partial reappearance from the decaying milfoil beds. The chemical had virtually disappeared from the system by late September. Calculated inflows and outflow showed that most of the chemical was not lost in the outflow, but was degraded in the lake. The appearance of 2,4-D in the lake in May, before the milfoil control season, was attributed to the spring runoff carrying residual 2,4-D from land applications of the previous year.

The pond and field studies showed that present 2,4-D uses in milfoil control are not likely to have significant effects on freshwater ecosystems or impair water quality, and that the chemical does not persist in the lakes, or accumulate in the sediments, beyond the growing season. (Nagy, Hart)

**Accumulation and Effects of Toxic Contaminants in Aquatic Biota.** Bioaccumulation studies are a necessary component of research into the fate of contaminants in polluted aquatic systems. They provide important information on contaminant behaviour, including bioavailability, routes and modes of entry into the biota, and responses to metabolic processes (persistence, transformation, degradation). Bioaccumulation studies also identify suitable indicator organisms for use in biomonitoring programs.

The differential bioaccumulation of chlorophenols, benzothiazoles and diphenylamine by common shiners, longnose dace and crayfish was studied on site at Canagagigue Creek, Ontario. After one week of exposure, crayfish were found to have the lowest bioconcentration capacity for all compounds, while the two species of fish were remarkably similar to each other. Concentrations of the various compounds in biota were not always proportional to water concentrations. For example, 2,4,5-TCP accounted for about 30% of the total chlorophenols in biota but only 15% in the water. In contrast, 2,6-DCP accounted for only 10% of the total chlorophenols in biota as compared with 21% in the water. Biota accumulated very high levels of 2-(methylthio)benzothiazole, as would be expected from the high concentrations of this compound in the water. However, the uptake of benzothiazole was surprisingly low. Tissue levels of this compound were similar to those for 2,4-DCP, yet concentrations of the former were  $15 \times$  higher in the water. Diphenylamine was present in the water at levels similar to 2,4-DCP, but it was three times more concentrated in the organisms. These results point out the futility of assessing the contamination of an ecosystem on the basis of contaminant concentrations in the water alone. This study is believed to be the first to investigate the bioaccumulation of benzothiazole derivatives by aquatic biota.

The comparative depuration rates of chlorophenols, benzothiazoles, lindane and DDT by the leeches *Dina dubia*, *Erpobdella punctata* and *Helobdella stagnalis* were determined in the laboratory. Contaminated leeches were collected from

Canagagigue Creek, then allowed to depurate their body burdens of contaminants in clean, flowing water for 28 days. The results are presented in Table 1. It is apparent that leeches have inefficient regulatory mechanisms for eliminating chlorophenols and DDT derivatives from their systems. These compounds were most persistent in *E. punctata*, the species which is the largest and has the longest life span. The rapid depuration of 2-(methylthio)benzothiazole is particularly noteworthy, as initial tissue concentrations of this compound were one to several orders of magnitude higher than any other compound.

The persistence of DDT and related compounds in biota is a general phenomenon. However, chlorophenols are known *not* to persist in fish and bivalves. This study demonstrates that leeches would be excellent biomonitors for detecting con-

tamination of a water body by chlorophenols. It also points out that not all organisms are suitable biomonitors for all compounds. Only laboratory studies such as this can identify the best biomonitors to use under various conditions of pollution. (Metcalf, Carey, Fox, Coletta)

**Atmospheric Deposition of Organic Chemicals.** During 1984, studies were continued on the deposition of persistent organic pollutants in the rainfall. Sampling has been expanded to include stations at Kouchibouguac National Park (New Brunswick) and Cree Lake (northern Saskatchewan); sampling at Caribou Island and Agawa Bay sites on Lake Superior was continued. Volume-weighted concentrations from the 1984 and previous seasons are presented in Table 2.

Table 1. Depuration Half-Lives (days) of Organic Contaminants by Leeches

Compound	Leech species		
	<i>Dina dubia</i>	<i>Erpobdella punctata</i>	<i>Helobdella stagnalis</i>
2,6-DCP	33	NSD	—
2,4-DCP	43	NSD	43
3,4-DCP	30	NSD	100
2,4,6-TCP	25	NSD	33
2,3,6-TCP	NSD	NSD	NSD
2,4,5-TCP	NSD	NSD	30
2,3,4,6-TTCP	NSD	NSD	NSD
PCP	NSD	27	NSD
p,p'-DDT	NSD	NSD	6
p,p'-DDE	NSD	NSD	NSD
p,p'-DDD	10	22	13
o,p'-DDE	NSD	NSD	60
o,p'-DDD	13	34	6
Lindane	<1	1	—
Benzothiazole	10	7	<1
2-(Methylthio) benzothiazole	2	3	—

NSD — No significant depuration over a period of one month.

Table 2. Weighted Averages of Contaminant Concentrations in 1984 Rain (ng/L)

Compound	1976/77 Batch- awana*	1983 Isle Royale	1983 Caribou Island	1984 Caribou Island	1984 Agawa Bay	1984 Kouchi- bougauac	1984 Cree Lake
α-BHC	14	36	15	6.5	6.7	13	6.5
Lindane	8	8.4	4.3	3.0	2.9	6.7	1.2
Heptachlor epoxide	ND	0.31	0.21	0.28	0.18	0.07	0.02
Dieldrin	0.67	ND	0.24	0.96	0.62	0.27	0.38
Endrin	ND	ND	0.02	0.07	0.08	0.66	0.24
pp'-DDE	ND	0.37	0.08	0.17	0.09	0.02	0.07
pp'-DDT	ND	0.03	0.17	0.46	0.11	0.19	ND
pp'-DDD	ND	0.79	0.02	0.06	ND	0.14	0.19
Methoxychlor	2	2.6	2.1	1.4	0.59	0.02	0.09
PCBs	33	6.7	5.9	2.5	3.2	1.1	3.1
HCB	ND	0.03	0.10	0.09	0.03	0.07	0.01
α-Chlordane	ND	ND	ND	0.06	0.02	ND	ND
γ-Chlordane	ND	ND	ND	0.20	0.06	ND	ND

\*Sensitivity and statistical soundness of data are not the same as others.

ND — Not detected.



There is an apparent downward time trend in concentrations for PCBs, alpha-BHC and lindane for the sites at Batchawana, Agawa Bay and Caribou Island, all of which are on the eastern side of Lake Superior. There also appears to be a downward, open-lake trend from west to east (Isle Royale and Caribou Island), and little or no difference between open-lake and on-shore locations (Caribou Island and Agawa Bay) over virtually identical time spans.

The concentrations of these compounds in rainfall from Kouchibouguac, Cree Lake, Caribou Island and Agawa Bay are not significantly different for the major contaminants in this medium and are highly suggestive that atmospheric deposition is comparable across the country, at least east of the Rocky Mountains. Plans are underway to sample in the Pacific region. In addition, a new, all-weather (i.e. rain plus snow) prototype sampler is being evaluated; this equipment includes automatic data recording as well as the wetfall only capability. (Strachan)

**Accumulation/Degradation of Toxic Organic Contaminants in Fluvial Ecosystems.** In the past few years, the major focus of this study has been the pathways of accumulation and degradation of chlorophenols. To provide data on the environmental distribution of these compounds, field sampling was conducted in the Fraser River Estuary, British Columbia, and the North Saskatchewan River, Alberta and Saskatchewan. Chlorophenol levels in water and biota from the North Saskatchewan River were low but both water and fish from the Fraser River Estuary had elevated levels of 2,3,4,6-tetrachlorophenol (2,3,4,6-TeCP) and pentachlorophenol (PCP). Bioconcentration factors for these compounds ranged from 100 for 2,3,4,6-TeCP in starry flounder to 1600 for PCP in sculpins. The isomer ratios and the geographical variation in levels implicated the lumber industry as the source of these chlorophenols to the Fraser River. A more detailed sampling program is planned for the coming year.

We have previously demonstrated that the CP isomers present in the ground water under the chemical disposal area appear to be the products of anaerobic dehalogenation of the original CPs disposed of there. This degradation pathway has now been confirmed in a series of laboratory experiments involving sediments from Windermere Basin, Hamilton Harbour. The steric course of the anaerobic dehalogenation of CPs was studied and ortho-substituents were shown to be the most reactive. In cases where both meta-positions are occupied by chlorine, the para-position is also reactive. Thus, pentachlorophenol (PCP) can undergo loss of three successive chlorines to give 3,5-dichlorophenol, whereas 2,3,4,6-tetrachlorophenol (2,3,4,6-TeCP) loses only two chlorines to give 3,4-dichlorophenol.

The environmental occurrence of this degradation route was confirmed at the site of a major chlorophenol spill which occurred in British Columbia in 1978. In collaboration with personnel from NWRI and NHRI, Pacific and Yukon Region, the ground water under the spill site was sampled. It was shown that whereas the material spilled contained only PCP and 2,3,4,6-TeCP, the ground water directly under the spill contained all the tetra- and tri-chlorophenols found in the laboratory dehalogenations of these compounds. In the field measurements, the half-life for loss of a chlorine via anaerobic dehalogenation was about 10 years. (Carey, Fox, Metcalfe, Coletta, Hart)

## ORGANICS-PROPERTIES SECTION

This Section determines chemical, physical and biological properties of organic contaminants, the qualitative and quan-

titative relationships between such characteristics, and their influence on the distributions, pathways and effects of these substances. Field and laboratory experiments are carried out to determine sources, pathways and sinks of xenobiotic compounds in water, suspended matter and bottom sediments of lakes and rivers, to identify new contaminants, to determine their water/octanol and water/sediment partition coefficients, adsorption/desorption rates, metabolic pathways, products and kinetics, and their toxic effects on representative aquatic bacteria, yeasts and fungi.

**Upper Great Lakes Connecting Channels Research (the Detroit and St. Clair Rivers – Pollution Issue).** The upper Great Lakes connecting channels, in particular the Detroit, and St. Clair rivers and Lake St. Clair, have been recognized as important parts of the Great Lakes ecosystem. These areas of concern are characterized by numerous industrial and municipal effluents, strong flow within the rivers and sedimentary zones in Lake St. Clair and the western basin of Lake Erie. Consequently, persistent contaminants entering this system may be adsorbed onto particulates, and may be sedimented and resuspended repeatedly. Furthermore, dredging of navigation channels, development of shoreline properties for industrial and residential uses, and changing water levels contribute significantly to sediment/contaminant interactions.

As part of a multidisciplinary investigation, Section staff undertook the sampling, analysis and interpretation of water, seston and sediment samples from over 200 stations for volatile and other organic contaminants, yeasts, fungi bacteria, acute toxicity, phenols, PCBs, organochlorines and polycyclic hydrocarbons. In addition, large-volume (200 L) water samples from over 70 stations were centrifuged on site, extracted with methylene chloride and will be analyzed by gas chromatography and mass spectrometry. Preliminary results indicate significant loadings of tetrachloroethylene (Fig. 14); carbon tetrachloride; 1,1,1-trichloroethane and trichloroethylene from the St. Clair River to Lake St. Clair. (Kaiser, Comba)

**Quantitative Structure-Activity Research (QSAR).** Quantitative structure-activity relationships (QSAR) are useful tools for the prediction of many biological and physico-chemical properties of compounds. In particular, bioaccumulation factors (BCF), acute and sublethal toxicities to many aquatic species have been found to be well correlated with molecular (for example ionization potential) and bulk (for example octanol/water partition coefficient [log P]) parameters of the chemicals.

Laboratory investigations on the toxicity (Microtox test) of over 60 chlorophenols, -anilines, -benzenes, -nitrobenzenes, and -pyridines show nearly parallel dependencies on log P of the mentioned groups (Fig. 15). Furthermore, the intercepts of these parallels were found to be related to the (molecular) hydrophilic effect parameter. Research is presently underway on a large series of 1,4-disubstituted benzene derivatives with different functional and substituent groups. (Kaiser, Ribo, Comba)

**Degradation of Toxic Organic Chemicals.** Degradation through chemical interaction with water (hydrolysis), by itself or of contaminant derivatives derived through oxidation, reduction, irradiation and metabolic processes, is a major removal mechanism for many toxic chemicals. Studies are undertaken to elucidate the mechanisms, products and rates of these processes for selected chemicals and contaminant groups.

Aniline and a total of seven chloro-anilines were exposed to four strains of yeast and yeast-like fungi, comprising two oxidative (*Rhodotorula*) and two fermentative (*Pichia* and



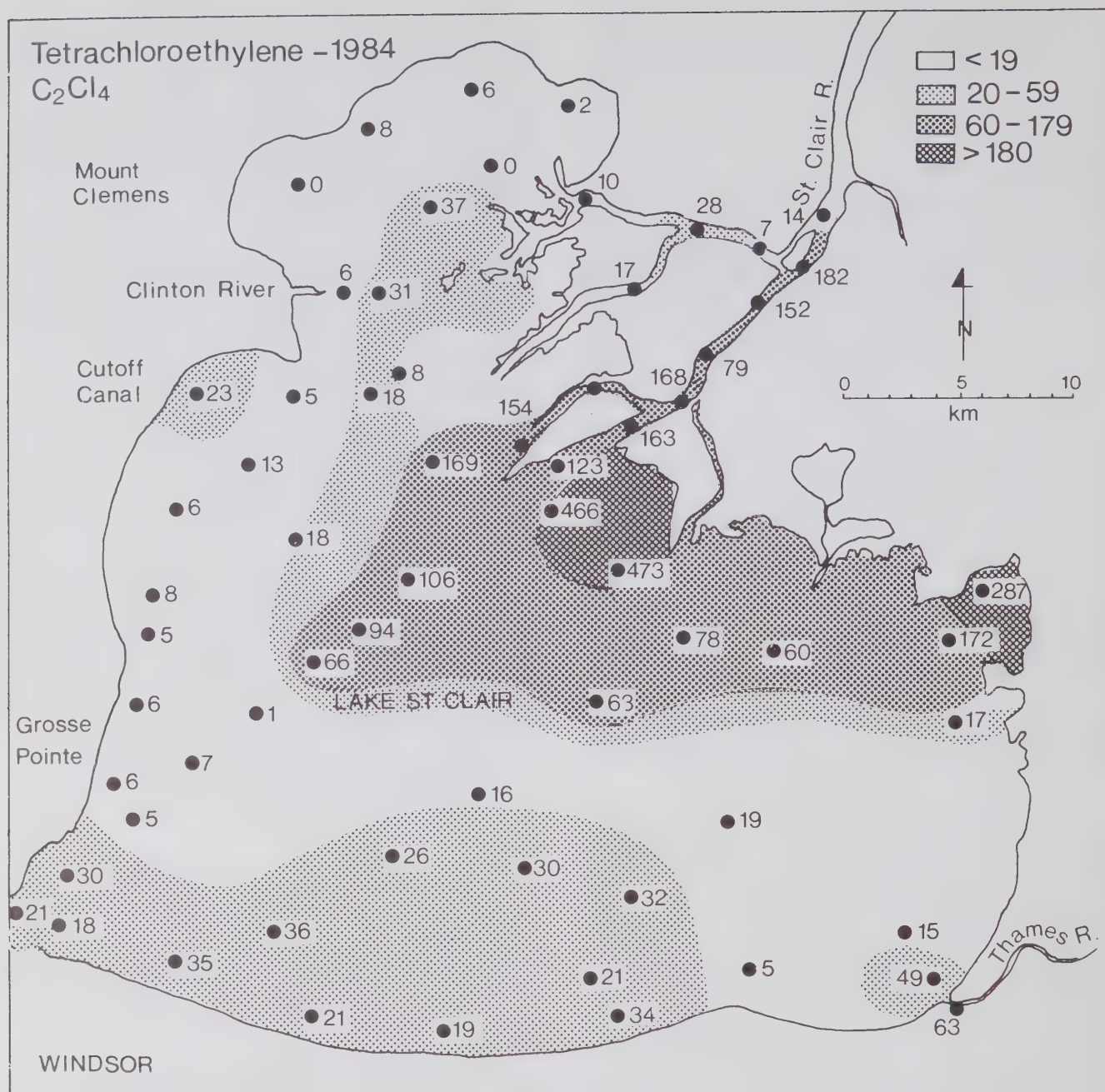


Figure 14. Tetrachloroethylene concentrations in Lake St. Clair surface water in summer 1984. All values are in nanograms per litre.

*Saccharomyces*) species. Partial degradation was observed for the lower chlorinated isomers and the concentrations producing growth reductions of 50% were quantitatively correlated with octanol/water partition coefficients of the isomers. (Kwasniewska, Kaiser).

Four intermediates during the microbial transformation of 2,4-dinitrotoluene have been identified, and two of these were nitroso compounds (2-nitroso-4-nitrotoluene and 4-nitroso-2-nitrotoluene), which are the hypothetical intermediates and have eluded previous detection. Two nitroso compounds were unstable and could be observed only at the early stage of 2,4-dinitrotoluene anaerobic degradation. This study demonstrated the possibility of treating the toxic nitro aromatics with anaerobic biodegradation techniques. (Liu, Thomson)

Chemical oil dispersants have been used to combat oil spills, but their fate in aquatic environments remains uncertain. A study showed that treatment of oil spills with chemical dispersants is unlikely to cause any build-up of organic contaminants in the aquatic environment. The application of biotechnology in the treatment of petroleum waste as well as in the assessment of a chemical's persistence and fate in the aquatic environment were also investigated in an effort to achieve the goal of technology transfer to industry and other governmental agencies. Due to the vast number of existing and newly introduced chemicals in the environment, there is a direct need for a rapid and accurate short-term bioassay procedure to assess the acute and sublethal toxicity of chemical compounds. Therefore, a rapid and inexpensive screening

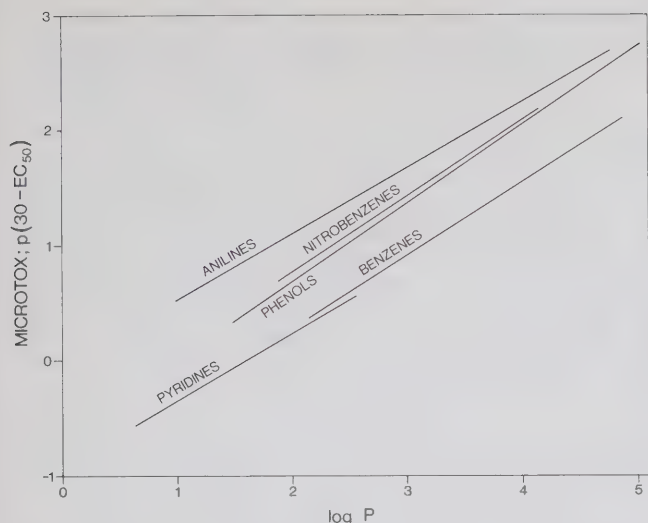


Figure 15. Plot of the toxicities (30-min Microtox test) of 68 chlorinated compounds versus their octanol/water partition coefficients (log P).

procedure based on the quantitative measurement of the interaction between toxicant and microbial dehydrogenase was developed for the toxicity assessment of water-soluble and water-insoluble chemicals. In addition, ten bacterial test systems for the screening of chemical toxicity were also systematically compiled into a book to facilitate the advancement of short-term bioassay. Since alkalinity may affect chemical toxicity, a micro manometric method based on the quantitative measurement of carbon dioxide liberated from a sample by an acidic buffer has been developed for assessing the alkalinity of natural water and wastewaters. To refine the short-term bioassay techniques further, factors affecting the structure-activity relationship were studied using various types of chemicals and bacteria. (Liu, Thomson)

Studies on the conversion of certain PCB components to insoluble humic-like materials have been completed and the results are now in press. An investigation of the biochemistry of pentachlorophenol degradation by bacteria was begun but was interrupted for a period of seven months due to the secondment of the scientist in charge to assist CIDA in Ethiopia. (Baxter)

**Contaminant Fate Research in the Great Lakes.** The potential availability of contaminants adsorbed onto sediment to benthic organisms and, through desorption directly to the water, has been of concern for a considerable time. Therefore, a study was undertaken to determine the uptake of several chlorinated hydrocarbons by aquatic worms from contaminated sediments. It was found that the concentration factor, CF (chemical concentration in worm/chemical concentration in sediment), varied considerably with chemical structure and sediment type. For example, CFs varied from 0.06 for 1,2,4,5-tetrachlorobenzene to 6.7 for octachlorostyrene — a difference of over two orders of magnitude. Because of the different CFs for various chemicals, the oligochaete worms contained a chemical mixture different from the sediment in which they lived. Thus, worm predators such as small fish would be subjected to a different chemical mixture than is found in the sediments.

In contrast to these results, the desorption of chlorinated chemicals from suspended sediments into the aqueous phase

changed very little with chemical structure. Temperature seemed to be the most important variable governing desorption rates. Desorption half-lives decreased from 60 days at 4°C to 40 days at 20°C to 10 days at 40°C under continuous purging of the organics from the water. Some crude estimates of the loadings of chemicals via desorption from bottom sediments in Lake Ontario were compared with loadings of these chemicals from the Niagara River. For compounds with low current loadings from the river, desorption from bottom sediments could play a significant role in controlling lake water concentrations. (Oliver, Nicol)

A two-year study on 31 chlorinated compounds in weekly samples from the Niagara River showed a measurable background concentration for most contaminants (likely because of steady leaching from chemical waste disposal sites along the river), and large unpatterned concentration spikes (likely because of direct chemical discharges to the river). Although some reduction in discharges has been achieved in recent years, this study shows that chemical dumping into the river is still a problem.

The river contaminants adsorbed to settling particles in Lake Ontario have been studied using sediment traps. Contaminant fluxes to the lake sediments were found to be much lower than anticipated, likely due to significant volatilization losses from the lake. The trace organic composition of sediment trap material revealed that considerable resuspension of bottom sediments is occurring in Lake Ontario, particularly during the winter months. (Oliver, Nicol, Charlton)

Studies on the uptake and elimination of contaminants by rainbow trout (with A. Niimi, Great Lakes Fisheries Research Branch) are continuing. The bioconcentration factors determined in these studies have been related to physical-chemical properties of the chemicals. The correlation is good for small compounds with low octanol-water partition coefficients. (Oliver, Nicol)

## INORGANICS SECTION

This Section determines the persistence and fate of inorganic and organometallic contaminants in aquatic ecosystems by conducting investigations of contaminated ecosystems and laboratory studies on the physical, chemical and biological factors that determine the persistence and fate of metals and organometals in aquatic ecosystems. Physical factors include atmospheric deposition to water, volatilization from water, and adsorption to suspended solids and sediment. Chemical factors include metal complex formation and speciation, hydrolysis and sunlight photolytic degradation. Biological factors include uptake by a variety of aquatic organisms, with subsequent transformation (e.g. methylation of metals) and degradation.

**Fate of Tributyltin in Aquatic Environments.** Tributyltin is a pesticide that is widely used as an antifouling agent in boat paint, as a slimicide in cooling towers, and as a general lumber preservative. It is very toxic to aquatic life. The goal of this study is to determine its occurrence, persistence and fate in aquatic ecosystems.

A survey of water and sediment for tributyltin from 250 locations in Canada is nearing completion. Preliminary results indicate that tributyltin is mainly found in harbours and marinas and other areas of heavy boating and shipping traffic, and this is probably due to its use as an antifouling agent in paint for boats, ships and docks. Table 3 shows some preliminary results on the occurrence of tributyltin.



Table 3. Tributyltin in Water, Sediment and Fish

Medium	Occurrence	Tributyltin concentration range	Most contaminated locations
Water	37 of 110 locations	0.01–18.10 $\mu\text{g}\cdot\text{L}^{-1}$	Toronto, Port Hope and Whitby harbours
Sediment	20 of 76 locations	0.01–3.52 $\text{mg}\cdot\text{kg}^{-1}$ dry weight	Toronto, Montreal and Whitby harbours
Fish	4 of 13 locations	0.01–0.02 $\text{mg}\cdot\text{kg}^{-1}$ dry weight	Hamilton Harbour

Twenty-two of the 37 water samples shown in Table 3 had concentrations exceeding the value of  $0.07 \text{ Sn } \mu\text{g}\cdot\text{L}^{-1}$ , which causes growth retardation in rainbow trout fry, and the tributyltin concentration at one location, Toronto Harbour, exceeded the 24-hour  $\text{LC}_{50}$  value of  $11 \text{ Sn } \mu\text{g}\cdot\text{L}^{-1}$  for adult rainbow trout. Thus there is cause for concern with regard to chronic toxicity of tributyltin to sensitive organisms in these areas. The toxicological significance of sediment-bound tributyltin is still in question. It has generally been assumed that adsorption of tributyltin to sediments constitutes a mechanism for removal from aquatic environments. We have, however, shown that oligochaete worms can take up tributyltin from sediment, thereby making it potentially bioavailable to bottom-feeding fish.

An intensive investigation of the environmental chemistry and fate of tributyltin showed that the main factors limiting the persistence of this pesticide were sunlight and bacterial degradation, and under Canadian conditions, the half-life is at least several months. The ultimate fate of tributyltin is probably conversion to harmless insoluble stannic oxide, and precipitation to the sediments. (Maguire, Tkacz)

**Occurrence and Fate of Alkylleads in Aquatic Environments.** Fish, sediment and surface water microlayer samples from the St. Clair and St. Lawrence rivers were found to contain significant concentrations of tetra-, tri- and dialkyllead species (where alkyl = methyl or ethyl), which are believed to be derived from tetraalkyllead antiknock production plants in the areas. Triethyllead is generally the most toxic of the alkyllead species to aquatic organisms. Freshwater clams (*Elliptio complanata*) accumulate triethyl- and trimethyllead in muscle and viscera, and apparently do not metabolize these species.

Alkyllead compounds are degraded by sunlight in successive dealkylation steps to inorganic lead. Half-lives of degradation are generally of the order of hours to days.

The abiotic methylation of lead (II) to methyllead (IV) by methyl iodide proceeds quickly. Such a process may be environmentally important in view of the presence of methyl iodide in natural waters, and may provide the reason for the existence of methyllead and methyltin species in natural waters remote from anthropogenic sources. Although environmental trans-methylations between some elements have been shown to occur, methyllead (IV) is probably not produced in such a fashion. Methyllead species, however, can transfer the methyl group to other metals such as tin.

Preliminary work has been done on the use of the adenylate energy charge ratio in phytoplankton as an indicator for environmental stress. The ratio is based on the concentrations of ATP, ADP and AMP in an organism. It may have great value as an indicator of environmental stress of pollution if, as hypothesized, the concept can be generalized to all levels of aquatic food chains. (Chau, Bengert)

**Bioavailability of Toxic Metals, Metalloids and Phosphorus in Aquatic Ecosystems.** A study of the geochemical availability of elements in bottom sediments of the Detroit River and western Lake Erie has shown that hydrous iron oxides are the dominant extrinsic factors controlling the environmental mobility of phosphorus, cadmium, zinc, cobalt, lead, chromium, nickel and manganese. In the aquatic ecosystem it is suggested that the presence of a large excess of iron over phosphorus (because of the implementation of abatement measures for the latter) is beneficial because of the efficient scavenging of inorganic contaminants. The Welland River was shown to contribute 12 t of zinc per year to Lake Ontario, which is 9% of the 136 t contributed by the Niagara River. This percentage is expected to rise, since the major source of zinc to the Niagara River, the Bethlehem Steel Corp., ceased steel-making operations in 1983.

Research is underway (1) to validate analytical methods for determining the speciation of cadmium and its availability in water, sediment and other environmental "compartments" and (2) to determine the geochemical pathways of inorganic contaminants in the St. Lawrence River and in Hamilton Harbour. (Lum, Kokotich)

**Metal and Metalloid Speciation and Bioavailability.** The association of metals with various sediment components was investigated by the separation of sediments from Lake Erie and the Niagara and Detroit rivers into seven size fractions. The geochemistry and mineralogy of each size fraction were determined together with concentrations of metals. The results indicated that most of metals were associated either with clay minerals or organic matter in Lake Erie. Fine particles from the Niagara and Detroit rivers contained up to 26 times higher concentrations of lead, zinc, copper, chromium and cobalt than fine particles from Lake Erie. These fine particles are susceptible to resuspension and transport from the Detroit and Niagara rivers into Lakes Erie and Ontario, respectively.

The Shubenacadie River headwater lakes in Nova Scotia are contaminated with arsenic and mercury as a result of past gold mining activities in the area. Studies of pathways of arsenic and mercury through the food chain showed significant uptake by benthic organisms, particularly aquatic worms, chironomids and clams. (Mudroch, Kokotich)

## RADIONUCLIDES SECTION

The major objective of this Section is to study the behaviour of both naturally occurring and artificially produced radionuclides in the Canadian aquatic ecosystems. Studies include the delineation of pathways of radionuclides discharged to rivers and lakes; the measurement of levels of these radio-



nuclides in water, biota and sediments; the development of methods for the determination of these radionuclides; and the application of predictive models for the dispersion of radionuclides in surface waters.

**Uranium-Series Radionuclides in Langley Bay, Lake Athabasca (Saskatchewan) Ecosystem.** Levels of these radionuclides have been measured in over 150 sediment, water, fish and aquatic plant samples in order to study the extent of radionuclide contamination due to an abandoned uranium mine waste site. A preliminary evaluation of the data indicates that the contaminants are being transported by sediments to Lake Athabasca. The radionuclide measurements are now being supplemented by stable element (20) data. The distribution of radionuclides in various fish organs is also being investigated. (Joshi, Platford, Thompson)

**The Port Granby Radioactive Waste Management Site.** Our analyses for radioisotopes leached from the site were completed in 1984. The concentrations in various locations at the site and downstream from it are given by symbols 3 through 9 in Figure 16. The concentrations of both  $^{226}\text{Ra}$  and/or uranium are within the maximum acceptable limits for drinking water (as set out by the Department of National Health and Welfare) at all points more than 1 m out from the shore of Lake Ontario. (Platford, Joshi, FitzGerald)

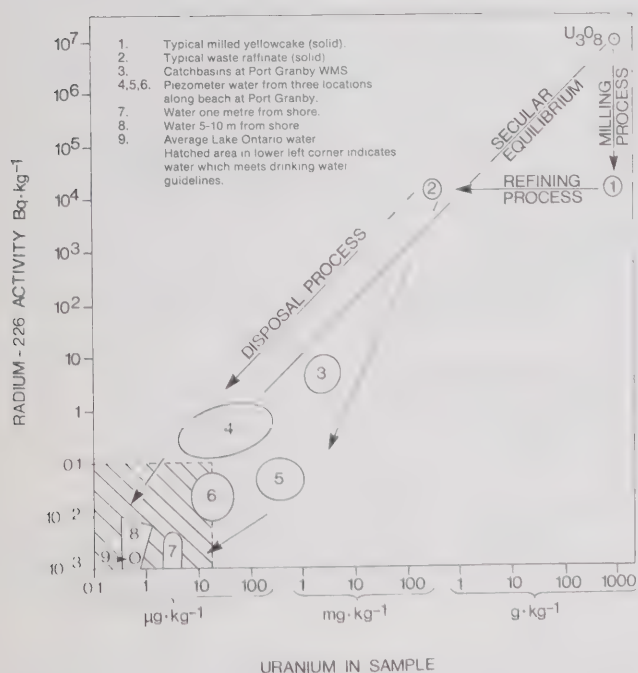


Figure 16. Radium/uranium ratio in typical solid and liquid compartments associated with the Port Granby site in Ontario, WMS — waste management site.

**Radionuclide Pathways in the Niagara River/Lake Ontario.** Levels of  $^{137}\text{Cs}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$ ,  $^{241}\text{Am}$  and various uranium and thorium isotopes have been measured in five  $^{210}\text{Pb}$ -dated sediment cores from Lake Ontario. A preliminary analysis of data shows that these locations receive non-fallout inputs of  $^{137}\text{Cs}$ ,  $^{238}\text{Pu}$ ,  $^{239,240}\text{Pu}$  and  $^{241}\text{Am}$ . A unique feature, common to all locations, is the incompatibility of the  $^{137}\text{Cs}$

profile with those for transuranics. Further work is underway to assess these profiles and the role of sediment mixing. (Joshi, Thompson)

## ACID DEPOSITION SECTION

The objective of research projects conducted by the Acid Deposition Section is to quantify and understand the hydro-geochemical response of acid-sensitive basins to the deposition of air pollutants. Two projects are underway, both utilizing the remote Turkey Lakes Watershed (TLW) as the field study site. The first study employs calculation of mass balances in the TLW to define the most important geochemical mechanisms controlling the "dose-response" relationship for this basin, and the second study is focussed on determining the factors or processes controlling the short-term acidification associated with spring snowmelt.

The TLW is an undeveloped, hydrologically calibrated basin (area = 10.5 km<sup>2</sup>), located 50 km north of Sault Ste. Marie, Ontario. It is completely forested (mixed hardwood) and contains a chain of five lake basins which exhibit a range of geochemical sensitivity and response to acidic deposition. For example, mean lake alkalinity increases from 0.04 to 0.19 meq·L<sup>-1</sup> from the headwater to the lowest lake in the chain.

**Geochemical Mass Balances in a Calibrated Watershed.** All data necessary for calculating lake mass budgets have been collected from June 1981 to May 1985. Mass budgets of ions for two "water-years" (June–May, 1981/82 and 1982/83) for a high elevation lake (Batchawana Lake South) and a low elevation lake (Turkey Lake) have been calculated. For example, budgets for selected parameters for the second water-year are given in Table 4. The budgets show that almost all of the hydrogen ion, but only part of ammonium and nitrate entering the lake are retained (Output – Input < 1); therefore all three species play an acidifying role in the TLW. Sulphate budgets are approximately in balance, that is, sulphate in the TLW is in a steady-state condition. Excess output of calcium and particularly alkalinity over input suggests the presence of unaccounted sources for these two ions. Probable sources include ground water and primary production; a possible source is within-lake alkalinity generation via sulphate reduction. The mass budget studies in the TLW are continuing. (Jeffries, Semkin, Neureuther, Seymour, Gough)

**Snowmelt and Acid Shock.** The accumulation and loss of ionic pollutants from the snowpack have been studied in the TLW since 1981. In 1985, a snow-box was used to contain (in

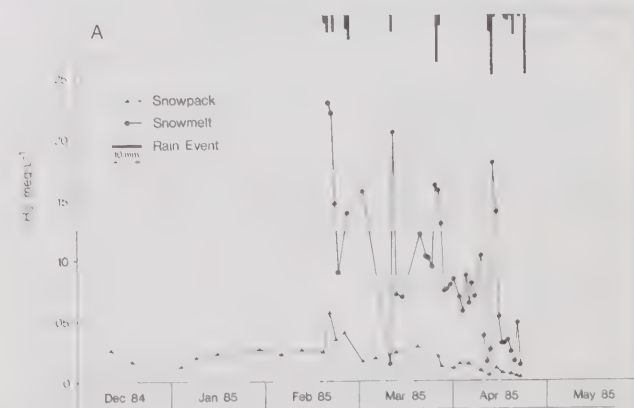


Figure 17. Hydrogen ion in snowpack and snowmelt.

Table 4. Mass Budget (kg) of Selected Ions for Batchawana Lake South and Turkey Lake for June 1982 – May 1983

Ion	Lake	Inputs			Total input	Total output	Out/I
		Bulk deposition	Terrestrial basin	Major inflow			
H	Batchawana	4.3	1.4	0.4	6.1	1.2	0.19
	Turkey	38	0	1	40	0	0
Ca	Batchawana	0.5	42.2	20.8	63.4	91.9	1.45
	Turkey	4	504	1043	1551	1972	1.27
NH <sub>4</sub>	Batchawana	1.5	0.4	0.8	2.7	2.3	0.85
	Turkey	14	2	3	18	10	0.57
Alk	Batchawana	-4.3	4.4	6.0	6.1	28.3	4.68
	Turkey	-38	249	580	788	1260	1.60
SO <sub>4</sub>	Batchawana	4.5	46.5	20.3	71.3	81.3	1.14
	Turkey	40	262	582	883	936	1.06
NO <sub>3</sub>	Batchawana	2.3	6.3	2.3	10.8	9.3	0.86
	Turkey	20	53	78	152	111	0.73

*situ*) the accumulating snowpack and later to channel all melt-water output plus rainfall into a "volume priority" fraction collector. An example of the hydrogen ion concentration in the snowpack and meltwaters is shown in Figure 17. Our studies show that in the TLW, the water quality of snowmelt water is strongly influenced by the occurrence of rainfall. In particular, the major acid anion accumulating in the snowpack is nitrate; with the influence of spring rainfall, however, the dominating anion in the meltwater is usually sulphate. (Jeffries, Semkin, English, Neureuther)

#### STAFF LIST

Chief — R.J. Allan, B.Sc., M.Sc., Ph.D., D.Sc.  
 Secretary — E.M. Kerr  
 Administrative Officer — F. Boyd

#### Organics-Pathways Section

##### Head

J.H. Carey, B.Sc., M.Sc., Ph.D. photodegradation of organic contaminants

##### Researchers

M.E. Fox, B.Sc. persistent organic contaminants in aquatic ecosystems  
 J.L. Metcalfe, B.Sc. biological fate of contaminants  
 E. Nagy, Dipl. Chem., M.Sc., Ph.D. fate and effects of herbicides  
 W.M.J. Strachan, B.A., M.A., Ph.D. organic contaminants in aquatic ecosystems, especially rain

##### Technical Staff

L. Coletta  
 J.H. Hart

#### Organics-Properties Section

##### Head

K.L.E. Kaiser, B.Sc., M.Sc., Ph.D. structure-activity correlations of organic contaminants

#### Researchers

R.M. Baxter, B.Sc., Ph.D. biochemistry and degradation products of PCBs  
 K. Kwasniewska, M.Sc. biodegradation of organic contaminants and toxicity to microorganisms  
 D.L.S. Liu, B.Sc., M.Sc., Ph.D. biodegradation of organic contaminants  
 B.G. Oliver, B.Sc., M.Sc., Ph.D. sources of aquatic organic contaminants, water chlorination by-products

#### Technical Staff

M.E. Comba  
 K.D. Nicol  
 K. Thomson, B.Sc.

#### Inorganics Section

##### Head

R.J. Maguire, B.Sc., Ph.D. aquatic fate of organometallics

##### Researchers

Y.K. Chau, B.Sc., M.Sc., Ph.D., D.Sc. chemical and biological processes of organometallics in the aquatic environment; metal speciation and toxicity  
 K.R. Lum, B.Sc., Ph.D. chemical forms of trace metals and geochemistry of particulate matter  
 A. Mudroch, Dipl. Chem., M.Sc. bioassays and geochemistry of sediments

#### Technical Staff

G.A. Bengert, B.Sc.  
 R.J. Tkacz, B.Sc.  
 E. Kokotich, B.Sc.

#### Acid Deposition Section

##### Head

D.S. Jeffries, B.Sc., Ph.D. geochemical processes controlling lake acidification; metal geochemistry



#### Researcher

R.G. Semkin, B.Sc., M.Sc., geochemical processes  
controlling lake acidification

#### Post Doctoral Fellow

M. English, B.Sc., M.Sc., Ph.D., snow chemistry

#### Technical Staff

M.D. Semour  
J. Longlade, B.Sc.  
R. Neureuther

#### Radionuclides Section

##### Head

S.R. Joshi, B.Sc., M.Sc., Ph.D., aquatic pathways of  
radionuclides

#### Researcher

R.F. Platford, B.A., M.Sc., Ph.D., physical chemistry of  
radionuclides

#### Technical Staff

J.A. FitzGerald  
S.P. Thompson, B.Sc.

K.L.E. Kaiser

UGLCC, Water Work Group

D.S. Liu

Standards Council of Canada

ASTM Oxygen Uptake Group

UN-FAO Marine Fouling Group

K.R. Lum

DOE Working Group on Cadmium

R.J. Maguire

Environmental Monitoring of Forest Insect Control  
Operations Committee

NRC Environmental Secretariat Panel on  
Organotins

ECA Chemical Evaluation Committee

A. Mudroch

Inland Waters Directorate Federal-Provincial Schu-  
benacadie Lakes Study Group

E. Nagy

AGRAD Working Group on Fate of Oil

B.F. Scott

International Standards Organization

DOE Ontario Region Environmental Emergency  
Team

W.M.J. Strachan

Interdepartmental Ontario Region Toxic Contam-  
inants Committee (GLWQA)

IJC/SAB Aquatic Ecosystem Objectives  
Committee (GLWQA) — Chairman

IJC/SAB-WQB Co-ordinating Committee for the  
Assessment of Chemicals (GLWQA)

DOE/NHW Toxic Chemical Committee (ECA)

### COMMITTEE MEMBERSHIP

R.J. Allan

Editorial Board, *WHO Water Quality Bulletin*

Editor-in-Chief, *Water Pollution Research Journal of Canada*

IJC Science Advisory Board (GLWQA)

J.H. Carey

Interdepartmental Ontario Region Toxic  
Contaminants Committee (GLWQA)

Y.K. Chau

NRC Environmental Secretariat Panel on  
Organotins

NSERC Environmental Toxicology Panel

Standards Council of Canada

M.E. Fox

Niagara and St. Lawrence River Surveillance Plan  
Task Force

D.S. Jeffries

Algoma Watershed Acid Rain Steering Committee

LRTAP Assessment Task Force of the Research  
and Monitoring Coordinating Committee

S.R. Joshi

DOE Nuclear Advisory Committee

Canadian Uranium Producers' Analytical  
Subcommittee

Canadian Advisory Committee/International  
Standards

Organization, TC/SC3-Water Quality/Radiological  
Methods

### PUBLICATIONS

**Allan, R.J.** 1984. The Canadian approach to water studies. Proc. Workshop on Surface Water Resources Data. Australian Water Resources Council Conf. Series No. 10, pp. 293–300.

**Allan, R.J.** 1985. The role of particulate matter in the transport and burial of contaminants in aquatic ecosystems. In *The Role of Particulate Matter in the Transport and Fate of Pollutants*, B.T. Hart (ed.), Pub. Water Studies Centre, C.I.T., Melbourne, Australia, Chapter 1, pp. 1–56.

**Allan, R.J.** 1985. The role of particulate matter in the bioavailability, recycling and bioaccumulation of contaminants in aquatic ecosystems. In *The Role of Particulate Matter in the Transport and Fate of Pollutants*, B.T. Hart (ed.), Pub. Water Studies Centre, C.I.T., Melbourne, Australia, Chapter 2, pp. 57–96.

**Allan, R.J., T. Brydges, D. Dodge, R.D. Hamilton, D.G. Jeffs, and K. Shikaze.** 1984. Mercury Pollution in the Wabigoon–English River System of Northwestern Ontario and Possible Remedial Measures. Final Report of the Steering Committee, Vol. 1, 18 pp. and Vol. 2, 538 pp.

**Baxter, R.M.** 1985. Environmental Effects of Reservoirs. In *Microbial Processes in Reservoirs*, D. Gunnison (ed.), Dr. W. Junk, Publishers, Dordrecht, Boston, Lancaster, pp. 1–26.

**Baxter, R.M.** 1985. Bacterial formation of humus-like material from polychlorinated biphenyls (PCBs). *Water Pollut. Res. J. Can.* In press.

**Bobba, A.G., D.C.L. Lam, D.S. Jeffries, D. Bottomley, J.Y. Charette, and L. Logan.** Modelling the hydrological regimes in acidified watersheds. *Wat. Air Soil Pollut.*



- Carey, J.H. (Panel member). 1985. TFM and Bayer 73: Lampricides in the aquatic environment. National Research Council of Canada, NRCC No. 22488.
- Carey, J.H., and S.A. Zaidi. Use of low pressure mercury lamps for the photodecomposition of iron cyanide in gold mill effluents. *J. Water Pollut. Res. Can.* In press.
- Carey, J.H., M.E. Fox, B.G. Brownlee, J.L. Metcalfe, and R.F. Platford. 1985. Disappearance kinetics of 2,4- and 3,4-chlorophenols in a fluvial system. *Can. J. Physiol. Pharmacol.*, 62: 971-975.
- Chau, Y.K. 1985. Analytical aspects of organo-metallic speciation in freshwater systems. In *The Importance of Chemical Speciation in Environmental Processes*, F.E. Brinckman and M. Bernhard (eds.), Springer-Verlag, Berlin. In press.
- Chau, Y.K., and P.T.S. Wong. 1985. Organo-group IV compounds in the environment. In *Organometallics in the Environment*, P.G. Craig (ed.), Longmans Press, London. In press.
- Chau, Y.K., R.J. Maguire, P.T.S. Wong, and M. Sanderson (eds.). 1985. The St. Clair River — Detroit River. Special Issue. *J. Great Lakes Res.*, 11: 191.
- Chau, Y.K., R.J. Maguire, P.T.S. Wong, B.A. Glen, G.A. Bengert, and R.J. Tkacz. 1984. Occurrence of methyltin and butyltin species in environmental samples in Ontario. NWRI Rep. No. 84-01.
- Chau, Y.K., P.T.S. Wong, G.A. Bengert, J.L. Dunn, and B. Glen. 1985. Occurrence of alkyllead compounds in the Detroit and St. Clair rivers. *J. Great Lakes Res.* In press.
- Comba, M.E., and K.L.E. Kaiser. 1985. Volatile halocarbons in the Detroit River and their relationship with contaminant sources. *J. Great Lakes Res.*, 11: 404-418.
- Cullen, J.M., and K.L.E. Kaiser. 1984. An examination of the role of rotational barriers in the toxicology of PCBs. In *QSAR in Environmental Toxicology*, K.L.E. Kaiser (ed.), D. Reidel Pub. Co., Dordrecht, pp. 39-66.
- Dafoe, T., J. Carey, S.H. McCrindle, P.G. Wells, and R.C.H. Wilson. 1985. Relationships between the biological testing of industrial effluents and the quality of receiving waters — Canadian approaches and examples. *Proc. of the OECD Workshop on Biological Testing of Effluents*.
- Dixon, D.G., P.V. Hodson, and K.L.E. Kaiser. 1984. The use of rapid biochemical indicators of toxicant stress to generate biological data bases for QSAR. *Proc. Workshop QSAR in Environmental Toxicology*, K.L.E. Kaiser (ed.), pp. 67-73.
- Dixon, D.G., C.B.A. Hill, P.V. Hodson, E.J. Kempe, and K.L.E. Kaiser. 1985. Plasma leucine aminoaphthylamidase as an indicator of acute sublethal toxicant impact in rainbow trout (*Salmo gairdneri*). In *Proc. 10th Ann. Aquatic Toxicol. Workshop*, Can. Tech. Rep. Fish. Aquatic Sci.
- English, M.C., D.S. Jeffries, N. Foster, and R.G. Semkin. The chemical and hydrological interaction of acid snowmelt waters with the terrestrial portion of a Canadian Shield catchment. Submitted to *Water Air Soil Pollut.*
- Fox, M.E. 1985. A practical sampling and extraction system for the quantitative analysis of organochlorine contaminants in filtered water and suspended solids. NWRI Rep.
- Fox, M.E., and S.R. Joshi. 1984. The fate of pentachlorophenol in the Bay of Quinte. *J. Great Lakes Res.*, 10(2): 190-196.
- Hashimoto, Y., K. Tokura, H. Kishi, and W.M.J. Strachan. 1984. Prediction of seawater solubility of aromatic compounds. *Chemosphere*, 13: 881-888.
- Hodson, P.V., D.G. Dixon, and K.L.E. Kaiser. 1984. Measurement of median lethal dose as a rapid indication of contaminant toxicity to Fish. *Environ. Toxicol. Chem.*, 3: 243-254.
- Hodson, P.V., D.G. Dixon, and K.L.E. Kaiser. 1984. Median lethal dose (LD50) as a rapid indicator of contaminant toxicity in fish. In *QSAR in Environmental Toxicology*, K.L.E. Kaiser (ed.), D. Reidel Pub. Co., Dordrecht, pp. 179-187.
- Hushon, J.M., A.W. Klein, and W.M.J. Strachan. 1984. Use of OECD premarket data exposure analysis for new chemicals. *Chemosphere*, 12: 887-910.
- Jackson, R.E., S.R. Joshi, and R.F. Platford (eds.). 1984. Radioactivity in the Canadian aquatic environment. Special Issue, *Water Pollut. Res. J. Can.*, 19(2): 148.
- Jeffries, D.S., R.G. Semkin, and R. Neureuther. 1984. Data report: Lake outflow hydrology (1980-1983). Turkey Lakes Watershed unpub. rep. No. TLW-84-01, 30 pp.
- Jeffries, D.S., R.G. Semkin, R. Neureuther, M. Seymour, and J.A. Nicholson. Assessment of the effect of acidic precipitation on the Turkey Lakes watershed using a mass balance approach. Submitted to *Water Air Soil Pollut.*
- Joshi, S.R. 1984. <sup>137</sup>Cs, <sup>226</sup>Ra and total uranium in fish from Lakes Ontario, Erie, Huron and Superior during 1976-1982. *Water Pollut. Res. J. Can.*, 19: 110-119.
- Joshi, S.R. 1985. Recent sedimentation rates and <sup>210</sup>Pb fluxes in Georgian Bay and Lake Huron. *Sci. Total Environ.*, 41: 219-233.
- Joshi, S.R. 1985. Lanthanum fluoride coprecipitation technique for the preparation of actinides for alpha-particle spectrometry. *J. Radioanal. Nucl. Chem., Articles*, 90: 409-414.
- Joshi, S.R. 1985. Determination of thorium-228, thorium-230 and thorium-232 in sediment by anion exchange and nuclear spectrometry. *Anal. Chem.*, 57: 1023-1026.
- Joshi, S.R., and M.E. Fox. 1985. The <sup>210</sup>Pb and <sup>137</sup>Cs profiles in sediment cores from Bay of Quinte, Lake Ontario. *J. Radioanal. Nucl. Chem. Articles*, 90(1): 207-215.
- Kaiser, K.L.E. (ed.). 1984. *QSAR in Environmental Toxicology*. D. Reidel Pub. Co., Dordrecht, Holland, 406 pp.
- Kaiser, K.L.E. 1984. Organic contaminants in the environment. Research progress and needs. *Environ. Int.*, 10: 241-250.
- Kaiser, K.L.E. 1985. Report on the workshop on QSAR in environmental toxicology, 16-18 August 1983, McMaster University, Hamilton, Ontario. In *Proc. 10th Ann. Aquat. Toxicol. Workshop*, Can. Tech. Rep. Fish. Aquatic Sci.
- Kaiser, K.L.E., and J.M. Ribo. 1985. QSAR of toxicity of chlorinated aromatic compounds. In *QSAR in Toxicology and Xenobiochemistry*, M. Tichy (ed.), Elsevier, pp. 27-38.
- Kaiser, K.L.E., P.V. Hodson, and D.G. Dixon. 1984. QSAR studies on chlorophenols, chloro-benzenes and para-substituted phenols. In *QSAR in Environmental Toxicology*, K.L.E. Kaiser (ed.), D. Reidel Pub. Co., Dordrecht, pp. 189-206.
- Kaiser, K.L.E., M.E. Comba, H. Hunter, R.J. Maguire, R.J. Tkacz, and R.F. Platford. 1985. Trace organic contaminants in the Detroit River. *J. Great Lakes Res.*, 11: 386-399.
- Kwasniewska, K. 1985. Biodegradation of crystal violet (hexamethyl-p-rosaniline chloride) by oxidative red yeasts. *Bull. Environ. Contam. Toxicol.*, 34: 323-330.
- Kwasniewska, K., and K.L.E. Kaiser. 1984. Toxicities of selected chloro-anilines to four strains of yeast. In *QSAR in Environmental Toxicology*, K.L.E. Kaiser (ed.), D. Reidel Pub. Co., Dordrecht, pp. 223-233.
- Lam, D.C.L., A.G. Bobba, D.S. Jeffries, and J.R.M. Kelson. Relationships of spatial gradients of primary production, buffering capacity and hydrology in the Turkey Lakes watershed. *Proc. ASTM Symp. on Biol. Effects Acid Precip.*, Bar Harbour, Florida. In press.
- Lam, D.C.L., S. Boregowda, A.G. Bobba, and D.S. Jeffries. Interfacing hydrological and hydrochemical models for simulating acidification effects in Canadian watersheds. Submitted to *Water Air Soil Pollut.*
- Liu, D. 1983. Fate of oil dispersants in aquatic environment. *Sci. Total Environ.*, 32: 93-98.
- Liu, D. 1985. Micro determination of carbonate alkalinity in water. In *Proc. of the 18th Annual Conference on Trace Substances in Environmental Health*, D.D. Hemphill (ed.), Columbia, Missouri, pp. 427-434.
- Liu, D. 1985. Effect of bacterial cultures on microbial toxicity assessment. *Bull. Environ. Contam. Toxicol.* 34: 331-339.
- Liu, D. 1985. Biodegradation of petroleum via fermentation. In *Biotechnology* P.N. Cheremisinoff and R.P. Quellet (eds.), Technomic Publications Co., Lancaster, Pennsylvania, pp. 103-134.
- Liu, D. Biodegradation tests. In *Toxicity Testing Using Microorganisms*, B.J. Dutka and G. Bitton (eds.), CRC Press, Inc., Boca Raton, Florida. In press.
- Liu, D. Resazurin reduction method for toxicity assessment of water-soluble and insoluble chemicals. Toxicity assessment. In press.
- Liu, D., and B.J. Dutka (eds.). 1984. *Toxicity Screening Procedures Using Bacterial Systems*. Marcel Dekker Inc., New York, 476 pp.
- Liu, D., and K. Thomson. 1984. Quantitative toxicity assessment of water insoluble chemicals. In *Toxicity Screening Procedures Using Bacterial Systems*, D. Liu and B.J. Dutka (eds.), Marcel Dekker Inc., New York, pp. 139-145.
- Liu, D., and K. Thomson. Biochemical responses of bacteria after short exposure to alkyltins. *Bull. Environ. Contam. Toxicol.* In press.
- Liu, D., K. Thompson, and A.C. Anderson. 1984. Identification of nitroso compounds from biotransformation of 2,4-dinitrotoluene. *Appl. Environ. Microbiol.*, 47: 1295-1298.
- Lum, K.R., and K.L. Gammon. 1985. Geochemical availability of some trace and major elements in surficial sediments of the Detroit River and western Lake Erie. *J. Great Lakes Res.*, 11: 328-338.
- Lum, K.R., M.E. Comba, P.R. Youakim, and E.A. Kokotich. 1985. A preliminary study of inorganic contaminants and water quality in the Welland River watershed. NWRI Rep. No. 85-63.
- Maguire, R.J., and R.J. Tkacz. 1985. Degradation of the tri-n-butyltin species in water and sediment from Toronto Harbour. *J. Agric. Food Chem.*, 33: 947-953.

- Maguire, R.J., R.J. Tkacz,** and D.L. Sartor. 1985. Butyltin species and inorganic tin in water and sediment of the Detroit and St. Clair rivers. *J. Great Lakes Res.*, 11: 320–327.
- Manning, P.G., **K.R. Lum,** H.K.T. Wong, and T. Birchall. 1985. Origin and age of the ferrihydrite layer in Lake Ontario sediments. *Can. Mineral.*, 23: 103–110.
- Metcalfe, J.L.,** and **A. Mudroch.** 1985. Distribution of arsenic and mercury in zoobenthos from the Shubenacadie River headwater lakes in Nova Scotia. NWRI Contribution No. 85-72, 30 pp.
- Metcalfe, J.L., M.E. Fox, P.A. Coletta,** and **J.H. Carey.** 1985. Chlorophenol levels in aquatic leeches from selected sites in southwestern New Brunswick. NWRI Contribution No. 85-61, 13 pp.
- Mudroch, A.** 1984. Particle size effects on concentration of metals in Lake Erie bottom sediments. *Water Pollut. Res. J. Can.*, 19: 27–35.
- Mudroch, A.** 1984. Chemistry, mineralogy and morphology of Lake Erie suspended matter. *J. Great Lakes Res.*, 10: 286–298.
- Mudroch, A.** 1985. Geochemistry of the Detroit River sediments. *J. Great Lakes Res.*, 11: 193–200.
- Mudroch, A.,** and S. Davies. 1985. Chemical speciation of metals in sediment elutriates. *Environ. Intern.*, 11: 89–94.
- Mudroch, A.,** N. Arafat, and S. Davies. 1984. Changes in chemical speciation of soluble metals in Quebec lakes. *Environ. Technol. Lett.*, 5: 237–244.
- Nagy, E.,** W.D. Taylor, and **J. Hart.** Degradation of 2,4-D in experimental systems containing bacteria and protozoa. Submitted to *Sci. of the Total Environ.*
- Niimi, A.J., and **B.G. Oliver.** 1985. Biological half-lives of chlorinated dibenzo-p-dioxins and dibenzofurans in rainbow trout (*Salmo gairdneri*). *Environ. Toxicol. Chem.* In press.
- Oliver, B.G.** 1984. The relationships between bioconcentration factors in rainbow trout and physical-chemical properties for some halogenated compounds. In *QSAR in Environmental Toxicology*, **K.L.E. Kaiser** (ed.), D. Reidel Pub. Co., Holland, pp. 301–317.
- Oliver, B.G.** 1984. Uptake of chlorinated organics from anthropogenically contaminated sediments by oligochaete worms. *Can. J. Fish. Aquat. Sci.*, 41: 878–883.
- Oliver, B.G.** 1984. Distribution and pathways of some chlorinated benzenes in the Niagara River and Lake Ontario. *Water Pollut. Res. J. Can.*, 19: 47–58.
- Oliver, B.G.** 1985. Desorption of chlorinated hydrocarbons from spiked and anthropogenically contaminated sediments. *Chemosphere*, 14: 1087–1106.
- Oliver, B.G.** 1985. Final report on the use of East Ghor Canal waters as a raw water source for treatment plant to supply domestic water to Amman, Jordan. NWRI unpub. rep. 85-77.
- Oliver, B.G.,** and R.A. Bourbonniere. 1985. Chlorinated contaminants in surficial sediments of Lakes Huron, St. Clair and Erie: Implications regarding sources along the St. Clair and Detroit rivers. *J. Great Lakes Res.*, 11(3): 366–372.
- Oliver, B.G.,** and M.N. Charlton. 1984. Chlorinated organic contaminants on settling particulates in the Niagara River vicinity of Lake Ontario. *Environ. Sci. Technol.*, 18: 903–908.
- Oliver, B.G.,** and **K.D. Nicol.** 1984. Chlorinated contaminants in the Niagara River, 1981 to 1983. *Sci. Total Environ.*, 39: 57–70.
- Oliver, B.G.,** and A.J. Niimi. 1983. Rainbow trout bioconcentration of some halogenated aromatics from water at environmental concentrations. *Environ. Toxicol. Chem.*, 3: 271–277.
- Oliver, B.G.,** and A.J. Niimi. 1985. Bioconcentration factors of some halogenated organics in rainbow trout: Limitations in their use for prediction of environmental residues. *Environ. Sci. Technol.*, 19: 842–849.
- Peterson, R.H., **J.L. Metcalfe,** and S. Ray. 1985. Uptake of cadmium by eggs and alevins of Atlantic salmon (*Salmo salar*) as influenced by acidic conditions. *Bull. Environ. Contam. Toxicol.*, 34: 359–368.
- Platford, R.F.,** A.G. Bobba, and **S.R. Joshi.** 1984. The Port Granby radioactive waste management site. *Water Pollut. Res. J. Can.*, 19: 90–96.
- Platford, R.F., J.A. FitzGerald,** A.G. Bobba, and **S.R. Joshi.** 1984. Report on the groundwater at the Port Granby radioactive waste management site. NWRI unpub. rep. 84-9.
- Platford, R.J., R.J. Maguire, R.J. Tkacz,** and N. Madsen. 1984. A note on the NWRI microlayer sample. NWRI Rep. No. 84-10.
- Platford, R.F., R.J. Maguire, R.J. Tkacz, M.E. Comba,** and **K.L.E. Kaiser.** 1985. The distribution of hydrocarbons and chlorinated hydrocarbons in various phases of the Detroit River. *J. Great Lakes Res.*, 11: 379–385.
- Ribo, J.M., and **K.L.E. Kaiser.** 1984. Toxicities of aniline derivatives to *Photobacterium phosphoreum* and their correlations with effects on other organisms and structural parameters. In *QSAR in Environmental Toxicology*, **K.L.E. Kaiser** (ed.), D. Reidel Pub. Co., Dordrecht, pp. 319–336.
- Ribo, J.M., B.M. Zaruk, H. Hunter, and **K.L.E. Kaiser.** 1985. Microtox toxicity test results for water samples from the Detroit River. *J. Great Lakes Res.*, 11: 297–304.
- Scott, B.F., **J.H. Carey, E. Nagy,** and R. Dermott. 1984. The fate of 3-trifluoromethyl-4-nitrophenol (TFM) in quiescent waters and its impact on benthos. *Water Pollut. Res. J. Can.*, 19(1): 59–65.
- Scott, B.F., **E. Nagy,** D.S. Painter, and W.D. Taylor. 1985. The fate and impact of 2,4-D on an aquatic ecosystem. NWRI Contribution No. 85–34.
- Semkin, R.,** and **D.S. Jeffries.** Storage and release of contaminants from the snowpack in the Turkey Lakes watershed. Submitted to *Water Air Soil Pollut.*
- Semkin, R.G., D.S. Jeffries,** and R. Neureuther. Relationships between hydrological conditions and the ionic composition of stream waters in the Turkey Lakes watershed. *Proc. Can. Hydrol. Symp.*, Quebec City, Quebec.
- Strachan, W.M.J.** 1983. Workshop on data bases for aquatic toxicology. In *Proc. 8th Annual Aquatic Toxicol. Workshop*, pp. 225–229.
- Strachan, W.M.J.** and C.J. Edwards. 1984. Organic pollutants in Lake Ontario. In *Toxic Contaminants in the Great Lakes*, J.O. Nriagu and M.S. Simmons (eds.), John Wiley, pp. 239–264.
- Thompson, J.A.J., M.G. Sheffer, R.C. Pierce, **Y.K. Chau,** J.J. Cooney, W.R. Cullen, and **R.J. Maguire.** 1985. Organotin compounds in the aquatic environment: Scientific criteria for assessing their effects on environmental quality. NRCC Associate Committee on Scientific Criteria for Environmental Quality, NRCC Pub. No. 22494, 284 pp.
- Wong, P.T.S., and **Y.K. Chau.** 1984. Structure – activity of triaryl phosphate in freshwater algae. *Sci. Total Environ.*, 32: 157–165.
- Wong, P.T.S., **Y.K. Chau,** J.S. Rhamey, and M. Docker. 1984. Relationship between water solubility of chlorobenzenes and their effects on a freshwater alga. *Chemosphere*, 13: 991–996.
- Wong, P.T.S., **R.J. Maguire, Y.K. Chau,** and O. Kramar. 1984. Uptake and accumulation of tin by a freshwater alga, *Ankistrodesmus falcatus*. *Can. J. Fish. Aquatic Sci.*, 41: 1570–1574.
- Wood, R.B., **R.M. Baxter,** and M.V. Prosser. 1984. Seasonal and comparative aspects of chemical stratification in some tropical crater lakes, Ethiopia. *Freshwater Biol.*, 14: 551–573.



## ANALYTICAL METHODS DIVISION

The Analytical Methods Division is responsible for the research, development and evaluation of new, improved and more cost effective manual and automated analytical techniques (including sample collection, preservation and screening procedures) for the measurement of chemical, biochemical and microbiological parameters in water, sediment, suspended solids, biological materials and effluents. Analytical methodology support is provided to the Water Quality Branch (National and Regional laboratories), the National Water Research Institute, the Great Lakes Water Quality Program, the Toxic Chemicals Management Program, the Long Range Transport of Airborne Pollutants Program, and other federal and provincial clients. The Division also conducts inter-laboratory quality assurance studies for all major water quality programs within the Department and provides centralized computer service to all components of the Canada Centre for Inland Waters.

Division personnel maintain close contact with scientists in other Canadian federal departments, provincial governments, U.S. federal and state agencies, and universities. In some cases collaborative studies are undertaken. The Division strongly supports the work of the International Joint Commission, the International Standards Organization, the American Society for Testing and Materials, the Federal Interdepartmental Committee on Pesticides and the Association of Official Analytical Chemists, by membership on committees and task groups.

The Division is made up of four sections: Analytical Chemistry Research, Quality Assurance and Methods, Microbiology Laboratories, and Computer Services.

### ANALYTICAL CHEMISTRY RESEARCH SECTION

The Analytical Chemistry Research Section is engaged in advanced methodology and instrumentation research. The research is directed toward the development of new or improved techniques for the identification and measurement of the priority chemical contaminants in water, sediment and biological material. The Section's main objective is to provide cost effective, validated analytical methods to other agencies within Environment Canada. During the last two years, emphasis has been on the use of analytical techniques such as high pressure liquid chromatography, gas chromatography, mass spectrometry, atomic and molecular spectroscopy, radioimmunoassay, electrochemical, continuous flow and flow injection analyses. The Clean and Hazardous Chemicals Laboratory is also managed by the Section.

The recent interest in supercritical fluid chromatography (SFC) at our laboratory is due to the potential advantages SFC has over high performance liquid chromatography (HPLC) and gas chromatography (GC). This interest was augmented by the development of small-bore column SFC. Small-bore columns are advantageous because column pressure drops are very low. The use of pressure or density programming to effect selectivity as opposed to gradient elution for HPLC or temperature programming for GC permits greater detection flexibility and the use of detectors such as the flame ionization detector. In the near future, we plan to use the mass spectrometer and, eventually, the nitrogen/phosphorus detection

system. SFC can be used to separate a variety of complex oligomeric mixtures of surfactants, nonionic fluorine-containing surfactant FC-171, polyglycerides with molecular weight over 1000 atomic mass units, and polycyclic aromatic hydrocarbons. Future work will concentrate on the application of SFC to environmental analyses. (*Onuska*)

A separation method is being developed for the identification of organic nitrogen-containing compounds in sediment samples. Prefractionation of heteroaromatic compounds (HAC) from sediments into discrete chemical classes is being performed by adsorption column chromatography using small quantities of neutral aluminum oxide and silicic acid. Subsequent high resolution separation of individual components has been achieved by using open tubular column-high resolution gas chromatography (HRGC). Specific compound types are determined by GC-retention data and HRGC/MS. The principal classes identified in solvent-refined coal liquid and petroleum extracts were aliphatic hydrocarbons, polycyclic aromatic hydrocarbons, nitrogen-containing HACs, and hydroxylated PAH fractions.

Water samples and suspended sediment samples from the Ottawa River were analyzed for base-neutrals, PCBs, chlorinated benzenes and organochlorine pesticides. Small quantities of PAHs and phthalates were confirmed by HRGC/MS, and traces of PCBs and OCs were identified by HRGC/ECD. Samples containing 2,3,7,8-TCDD were analyzed by HRGC/HRMS, and a minimum detection limit of 2 ppt in fish and sediment was established. Numerous samples suspected of containing 2,3,7,8-TCDD were analyzed for the Water Quality Branch. (*Onuska*)

Various methods of sample treatment, extraction and cleanup were evaluated in order to develop a suitable analytical scheme for selective determination of polychlorinated dibenzo-p-dioxins by HRGC/ECD or HRGC/MS in a variety of environmental samples. Samples containing dibenzofurans were also subjected to the cleanup and separation procedures. Recoveries of 85% to 98% were obtained. The transfer of this technology to the National Water Quality Laboratory has been completed. Considerable time and resources were spent to maintain the operation and services of the Clean and Hazardous Chemicals Laboratory for internal and external clients.

Radioimmunoassay (RIA) techniques have been proposed for the rapid and inexpensive screening of large numbers of environmental samples for polychlorinated dibenzo-p-dioxins and other trace organic contaminants. A procedure was adapted for labelling 2,3,7,8-TCDD with  $^{125}\text{I}$ , and purifying and characterizing the reaction products on a repeatable basis. The repeatability of the RIA for PCDD was established using 2,3,7,8-TCDD standards, and the assay was standardized and calibrated. A variety of environmental samples and potential interferences were analyzed using RIA. The interfacing of the RIA for PCDDs with an extraction and cleanup procedure is in progress. A new method for solubilizing PCDDs for analysis by RIA was developed and is being evaluated. (*Sherry, Wilkinson*)

The presence of the pesticide toxaphene in the aquatic environment is a major concern to those responsible for water management. A study was undertaken to develop a method that would measure the concentration of toxaphene and that could be easily transferred to the National Water Quality Labo-



ratory. To this end, the existing organochlorine methodology was modified and the extracts analyzed by capillary detector. The success of the method relies on the selection of suitable peaks to quantify the material. It was found that under specific operating conditions, there were 48 peaks that individually contributed at least 0.7% to the toxaphene formulation. From these peaks, 11 peaks were selected that were not susceptible to interference by other common organochlorines and were recovered quantitatively through the cleanup steps. Under normal conditions using split/splitless GC injection techniques, a minimum of  $10^{-10}$  g could be detected. (Scott)

A continuous liquid-liquid extractor was designed for the extraction of organics from large water samples. This development was undertaken to lower detection limits in the determination of organics, such as organochlorines, pesticides and PCBs. The extractor (Fig. 18) uses a combination of a mixer settler and a counter-current packed column. Two sizes of extractor have been constructed, one for sample flows of up to  $500 \text{ mL} \cdot \text{min}^{-1}$ , and the other for flows up to  $1 \text{ L} \cdot \text{min}^{-1}$ . These extractors have been used to extract up to 50-L water samples with about 150 mL solvent. The practicality of the design has been confirmed by operating them in the laboratory, on board ship and in a vehicle in the field. The preliminary results show that they give essentially complete extraction of the organics. (Goulden)

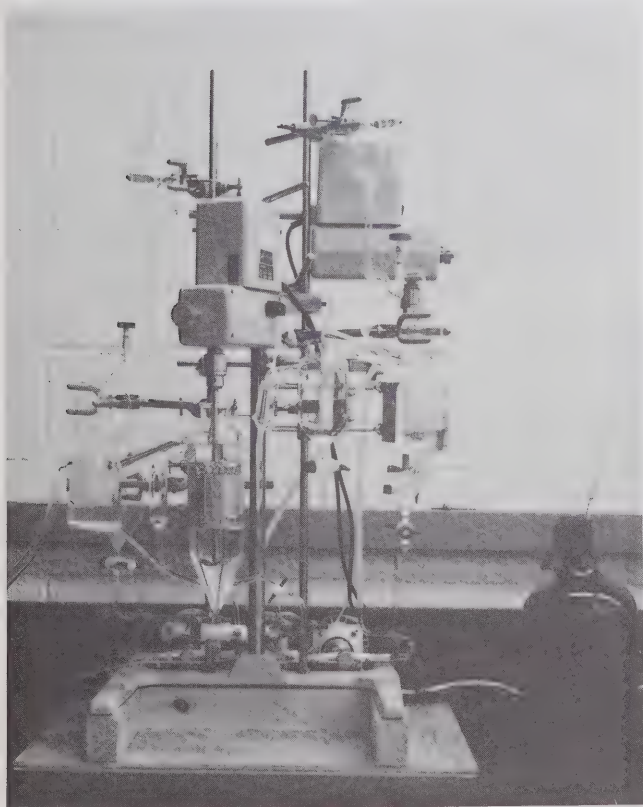


Figure 18. Large sample extractors set up for sequential acid-base/neutral extractions.

**Inorganic Parameters.** Flow injection analysis (FIA) has been adapted for automated sample delivery in atomic absorption spectroscopy. It entails automated insertion of discrete volumes of the sample into a constantly flowing lan-

thanum solution. The system achieves Ca and Mg analyses with high precision (less than 2% relative standard deviation) and low detection limits (1 ppb) at speeds of 120 to 140 samples per hour.

An FIA method for determination of dissolved oxygen has been developed. Samples preserved at the acid stage of the Winkler method are injected into a standard reagent stream and measured by spectrophotometry. Achieved precision is 2% relative standard deviation and the detection limit is 0.05 ppm D.O. at a sampling rate of 100 samples per hour.

Flow injection analysis methods using colorimetric detection for  $\text{NH}_4^+$ ,  $\text{PO}_4^{3-}$ ,  $\text{NO}_3^-$  and  $\text{NO}_2^-$  have also been developed. Simultaneous determination of all four parameters can be performed at a speed of 90 samples per hour. Relative standard deviations are less than 2% and required limits of detection are achieved. A simultaneous calibration curve for  $\text{NH}_3$  and  $\text{NO}_2^-$  is shown in Figure 19.

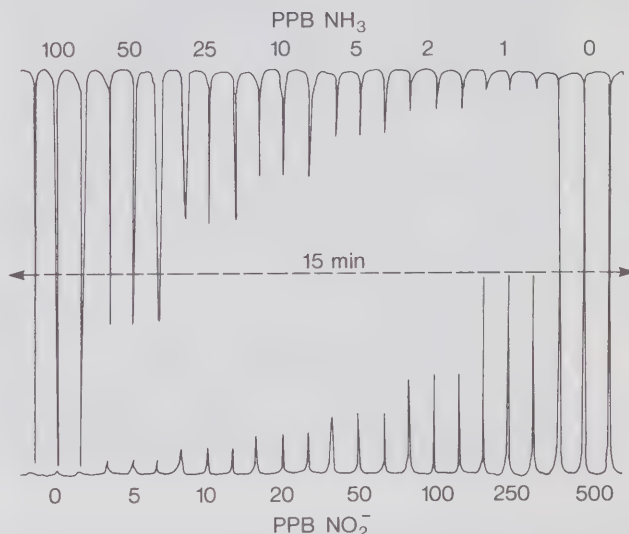


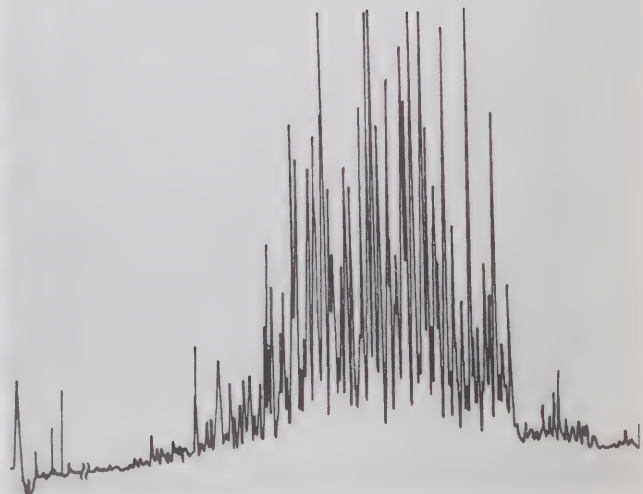
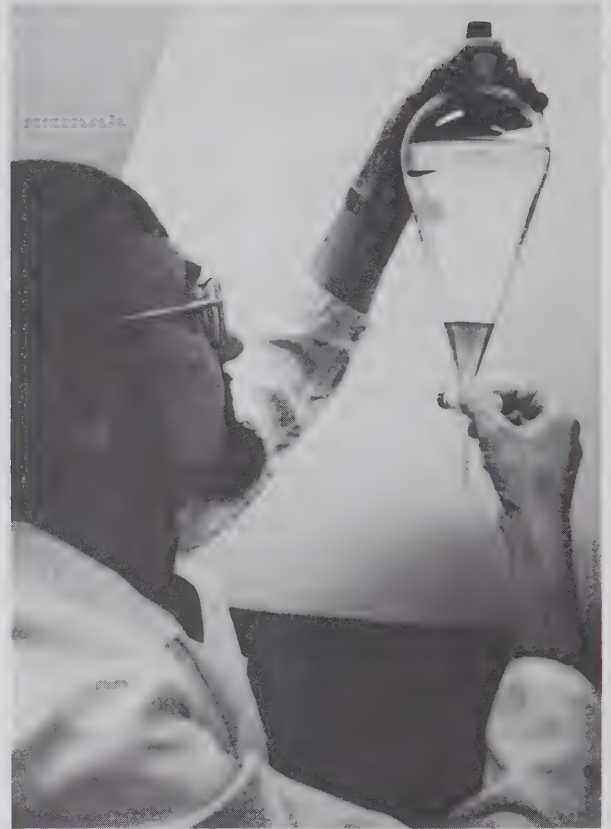
Figure 19. Simultaneous calibration of FIA methods for  $\text{NH}_3$  and  $\text{NO}_2^-$  using colorimetric detection.

Procedures for preservation of water samples for analysis of dissolved oxygen, cyanide and iodide have been developed and evaluated. The procedure for dissolved oxygen is by fixation at the acid stage of the Winkler method. This stabilizes the sample for up to eight weeks. Cyanide samples preserved with NaOH remain stable for nine weeks. Using the developed fixation procedure, iodide samples can be stabilized for up to seven weeks.

Electrochemical methods for sub parts per billion levels of Cu, Cd, Pb and Zn (flowthrough differential pulse stripping voltammetry) as well as for low levels of  $\text{CN}^-$  (gas permeable accumulation and amperometric detection) are in progress. (Sekerka)

A study was made of the relative suitabilities of an inductively coupled argon plasma (ICAP) and a microwave excited helium plasma (MIP) as the sources in an element-specific detector for capillary column gas chromatography. The results showed that MIP is more suitable for the determination of Br, Cl and F; both sources are equally suitable for the determination of C, P and S; and ICAP is the preferred excitation source for the determination of organometallics such as Sn and Pb. (Goulden)

## “Research in Action”





## QUALITY ASSURANCE AND METHODS SECTION

The work of the Section comprises three main areas: quality assurance (QA); development of reference and certified reference materials (RMs and CRMs); and methods development. The quality assurance programs involve the design and implementation of several types of quality control (QC) studies as well as investigations of sample homogeneity and stability. These QA programs assess the analytical performance and ensure the generation of reliable, valid and comparable analytical data on a regional, national and international basis. Only by collecting and using data with specified tolerance limits can we be sure that spatial and temporal trends are statistically significant and that data from different laboratories are comparable. Development of CRMs and RMs is essential to increase the effectiveness of these quality control studies.

**Quality Assurance (QA).** Two new studies have been initiated in 1985:

- (1) Federal-Provincial Water Quality Monitoring Agreement QA Program. In response to the Agreement between Environment Canada and the Province of Quebec, a new QA program was developed and initiated in July of 1985. Six QA studies have been distributed to date. (*Gorrie*)
- (2) Upper Great Lakes Connecting Channel Studies (UGLCCS)-QA Program. This binational (U.S. and Canada) program was initiated in late 1984. An overall QA program was developed and individual studies will start in 1986. The Section takes a lead role in the data quality management for the UGLCCS, advising on data quality and conducting interlaboratory studies. (*Chau*)

In addition to these activities, the Section actively continued its ongoing national and international quality assurance studies.

The Long Range Transport of Air Pollutants (LRTAP) QA study was initiated in 1982 in response to a concern about data comparability and quality among laboratories generating data for the LRTAP program. Each year, three multi-sample interlaboratory comparison studies for 40 inorganic parameters in water are designed and sent out to approximately 60 Canadian and several U.S. laboratories. Integrated reports based on percent bias and percent flagged statements are sent to all participants. (*Dookhran*)

The Prairie Provinces Water Board QA study, initiated in September 1982, is designed to assess and improve the comparability of water quality data generated by federal and prairie provincial laboratories (Alberta, Saskatchewan and Manitoba). Twelve studies, each involving 40 inorganic parameters, are conducted each year. Extensive computer programs and several data files are being generated to meet the objectives of the study. (*Alkema*)

Under the auspices of the International Joint Commission, a QA study specifically designed for dredging programs in the Great Lakes Basin was initiated in September 1983. There are four key components in this study: design and conduct of intercomparison studies; development of specific certified reference samples; design of suitable computer programs to assess comparability and short- and long-term laboratory performance; development of QA criteria for analytical contracts for dredging programs. Three interlaboratory studies were completed in this report period. (*Lee*)

The National QC Study includes over 100 federal, provincial, university and private laboratories and contains both inorganic and organic parameters in water and sediment. These national studies serve (1) to assess methodology and data of the

Water Quality Branch laboratories by comparison with peer laboratories, (2) to establish laboratory performance of Water Quality Branch and private laboratories, (3) to permit selection of private laboratories for contract analyses, and (4) to provide additional data for certification of reference materials. This year one interlaboratory study for PAHs in sediment and one for  $\text{SO}_4^{=}$  in coloured waters were conducted. (*Lee, Cheam*)

The Section has also provided a lead role in QA for the International Joint Commission's Great Lakes International Surveillance Program. International intercomparison studies for phosphorus in effluents, trace metals in water and organics in fish have been conducted this year. (*Aspila*)

A QA study for herbicides was designed and conducted under the auspices of the Federal Interdepartmental Committee on Pesticides. (*Lee*)

Research and development of certified reference materials continued in support of the quality assurance programs. Two sediment CRMs for polynuclear aromatic hydrocarbons (PAHs) are now completed, and a third sediment for PAHs is at its final stage of certification. These PAH CRMs are the first of their type available. (*Lee*)

**Sample Stability and Preservation.** The centralization of the Inland Waters Directorate Water Quality Branch laboratories has resulted in longer time periods between sample collection and sample analysis. Since a major consideration in the reliability of any laboratory measurement is that of sample integrity, technological needs for the sample processing and handling prior to analysis must be addressed. Phase 1 of a preservation study (major ions and nutrients) was completed in 1984, and phase 2 (trace metals) was completed in 1985. (*Arafat*)

**Methods Development and Technical Transfer.** Analytical methods for the following parameters in water were developed: chlorophenols (by *in situ* acetylation, chloroacetylation and pentafluorobenzyl ether formation); 10 acid herbicides by gas chromatography; 11 triazines by gas chromatography; and a multi-class multi-residue method for some 45 organic parameters in water and sediment. The herbicide methodology was transferred to the Water Quality Laboratory for routine application. (*Stokker, Lee*)

## MICROBIOLOGY LABORATORIES SECTION

The Microbiology Laboratories Section has two main functions. The first is to develop, evaluate and modify microbiological methods and criteria for assessing and monitoring water quality. These methods are distributed nationally and internationally through a methods manual entitled "Microbiological Analysis of Waters, Wastewaters and Sediments." To validate the methods, they are used routinely in field and laboratory studies to obtain a data base. Recent studies have been primarily devoted to toxicant screening tests, with a smaller proportion of time being spent on enumeration and isolation techniques related to bacterial populations in sediments, water, sewage and industrial waters.

The second major role that the Microbiology Laboratories Section fulfills is the application of the technologies mentioned above to environmental research. The main thrust of this research is to study the effects of acid rain, and industrial and domestic wastes on microorganisms in the aquatic ecosystem, and the reactions of these contaminated waters and sediments to various microbiological toxicant screening tests.



During the period covered by this report, Microbiology Laboratories Section staff concentrated their efforts in four main areas:

- (1) Completion of the cross-Canada distribution pattern study on Legionnaire's Disease Bacillus (*Legionella*).
- (2) Initiation of a four-continent study on the use of coliphage as indicators of water quality.
- (3) Evaluation of the effects of acid rain on toxic metal interactions with bacteria in aquatic systems.
- (4) Completion of a microbiology study of Lake St. Louis sediments, emphasizing microbial responses to loadings and toxicant distribution patterns based on microbial screening tests.

Microbiology Laboratories staff were also involved in the organization of two international symposia. The First International Symposium on Aquatic Microbial Ecology held at CCIW on May 13–15, 1985, was co-chaired by S.S. Rao. A total of 37 papers were presented by delegates from ten countries. The Second International Symposium on Toxicity Testing Using Bacteria was held on May 6–10, 1985, at the Banff Centre, Alberta. Sixty papers were presented at this symposium by delegates for 21 countries. D. Liu and B.J. Dutka, Co-Chairmen of the Toxicity Symposium Committee, coordinated and managed the symposium with the Department of Environment, Alberta, as the co-sponsor.

Microbiology staff also collaborated with a number of international methods development organizations for microbiology water quality, such as ASTM, APHA standard methods, International Standards Organization, and the AWWA Microbiology Problems Working Group. Microbiology staff participated in several other projects such as Lake Erie studies to ascertain the effects of reduced material loadings on bacterial populations and activities; an inshore Lake Ontario sediment survey (Kingston to Niagara River) to evaluate a battery of microbiological analytical techniques, e.g., fecal sterols, fecal coliform MF and MPN and toxicant screening tests, in order to develop a composite "hot spot" map based on a new battery of biochemical, microbiological and toxicant screening tests; and a study of the Ottawa River at Lemieux Island to evaluate the effect of improved sewage treatment processes on Ottawa River quality by means of bacterial enumeration and toxicant screening tests.

**Legionella Studies.** In 1982/83, in conjunction with the Department of National Health and Welfare, a national survey on the distribution patterns of *Legionella* organisms in natural waters, potable waters and cooling tower waters was initiated with a study centred on southern Ontario. In 1983/84, this survey expanded to include Lake Superior, the rivers and lakes of New Brunswick, Nova Scotia, Prince Edward Island and eastern Quebec, as well as potable water distribution lines and cooling tower waters from buildings in the following cities: Vancouver, Edmonton, Calgary, Poplar River, Regina, Winnipeg, St. Catharines, Mississauga, Ottawa, Montreal, Quebec City, Fredericton and Halifax. During the 1984/85 fiscal year, this cross-Canada study was completed by the collection of water samples from rivers, lakes and hot springs in British Columbia, Alberta, Manitoba, and western and northern Ontario. These studies indicated that Legionnaire's Disease Bacillus could be found in waters across Canada and that this organism is a normal water bacterium. (Dutka)

**Coliphage Evaluation.** In 1983, the International Development Research Centre (IDRC) in Ottawa initiated, with the aid and recommendation of Microbiology Laboratories Section

staff, a project in S.E. Asia (Singapore, Malaysia and Thailand) to evaluate coliphage as an indicator of water quality and health risks. To support this IDRC initiative and provide a Canadian data base, a research study was conducted to evaluate the coliphage procedure in Canadian waters. Water samples for this study were collected from the Fraser River (B.C.), Ottawa River, St. Lawrence River and Lake Ontario. In early 1985, a further international part of this study was initiated by involvement of three South American countries (Brazil, Chile, Peru) and three North African countries (Egypt, Tunisia, Morocco). (Dutka)

**Acid Rain Microbiology.** The effects of acid stress on bacterial activity and bacterial interactions with toxic metals in aquatic environments are of primary importance in the study of the effects of acid rain on aquatic ecosystems. Several sediment cores from Ontario lakes receiving acid precipitation were examined for (1) bacterial activity, (2) toxic metal concentration and (3) assessing the role of certain bacterial species in the sediment sulphate reduction process.

It was demonstrated that low pH stress changed the bacterial cell envelopes, as shown in Figure 20. Bacterial respiration rates, which in turn resulted in a diminution of the normal nutrient cycling processes and bacterial organic matter degradation processes, were altered. Under laboratory conditions, it was shown that acid stressed or low-pH stressed bacteria responded to toxic metals such as copper and aluminum to varying degrees. At pH 5, bacteria responded to copper by forming electron dense particles within their cell envelope, whereas aluminum stressed cells exhibited pleomorphism. This "bacteria-toxic-metal" association at low-pH stress conditions may have important implications in acid stressed lakes, if related to bacterial associated transport of toxic substances through the food chain. Another important aspect of lake acidification process is the accumulation of sulphur at the surface sediments. A joint study by the staff of Microbiology Laboratories, McMaster University and Brock University revealed that sulphate-reducing bacteria in the deeper layers of the sediment contributed to the excessive sulphur by bacterial sulphate reduction. (Rao)

**Lake St. Louis Sediments.** The discharge of contaminants and toxicants into the Great Lakes water systems by municipal and industrial wastewater systems is of much concern. The long-term effects of toxicants to aquatic life, their distribution patterns, transportation and biodegradation rates are being studied within the Canadian Great Lakes Drainage System. The Microbiology Laboratories Section joined with other researchers to provide information on the distribution of toxicants within the sediments and to establish baseline values for long-term monitoring. To this end over 100 water and sediment samples were collected from 50 stations and were tested for total bacteria, respiring bacteria, aerobic heterotrophic bacteria, and certain physiological types of bacteria such as  $N_2$  cycle and S-cycle bacteria. Other tests used on these samples were the Microtox test for toxicant screening data (Fig. 21) and ATP estimations for estimating toxic effect on *in situ* microbial biomass. Preliminary analyses of these data indicate that areas of high and low bacterial densities exist in the sediment, and the lower density areas are generally associated with areas where high concentrations of toxicants are found. Eighty-six percent of the surface sediments (3 cm) and 100% of the deeper sediments (10 cm) were found to contain toxicants, indicating that the effects of remedial actions are being seen in the surface sediments. (Rao, Kwan, Dutka)

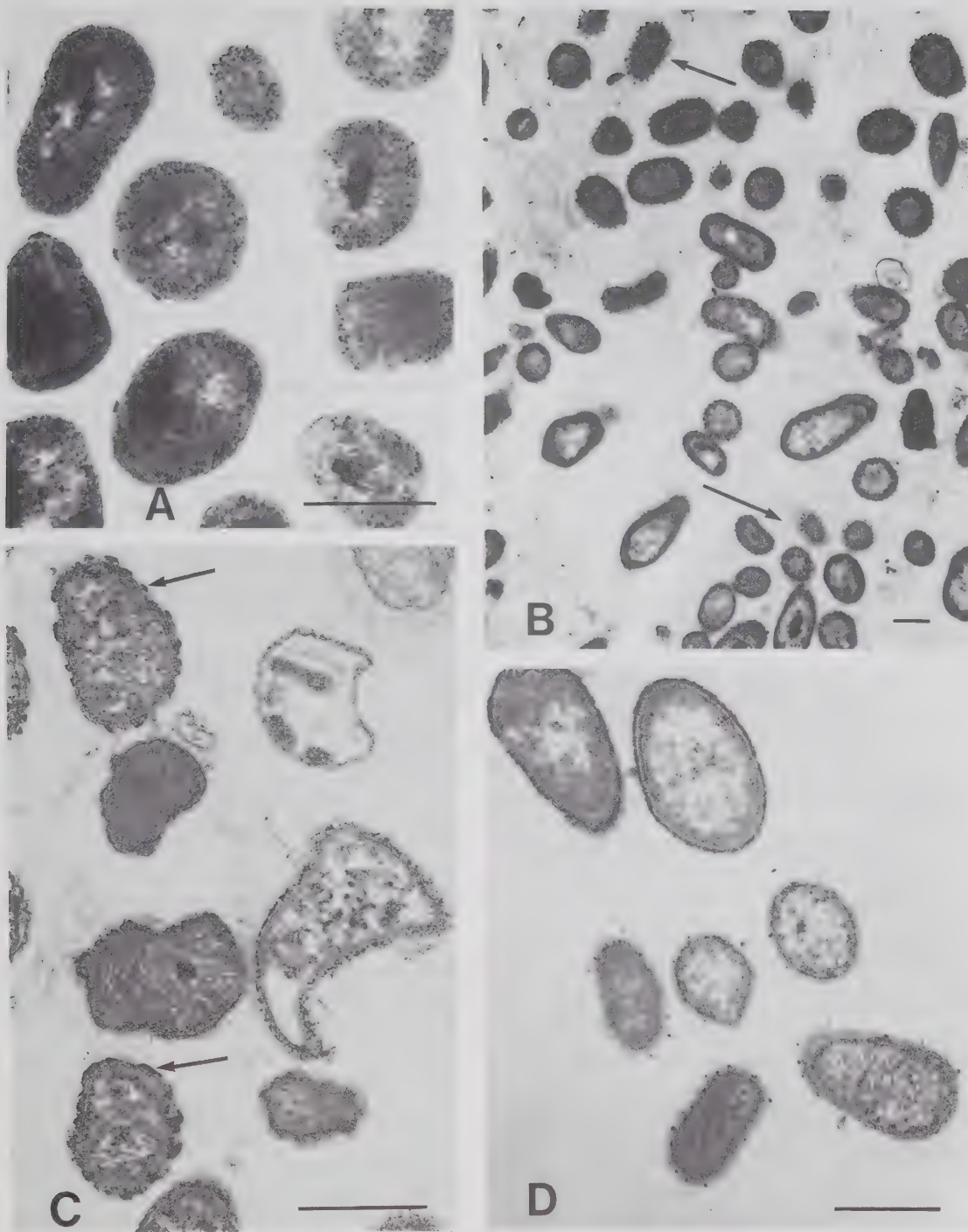


Figure 20. Cell envelope changes as a function of pH in mixed bacterial populations derived from McFarlane Lake, Ont. The marker represents 0.5  $\mu\text{m}$ ; A — cells at pH 7; B — cells at pH 6; C — cells at pH 5; D — cells at pH 4.





Figure 21. Sample being processed for toxicity by the Microtox Toxicity Screening Procedure.

## COMPUTER SERVICES SECTION

The Computer Services Section provides operational and system software support for the large-scale computing facilities at the Canada Centre for Inland Waters. Services are made available to all components of the Centre, since much of current environmental research is dependent on the availability of adequate computing resources. The Section's work affects many NWRI research programs.

The Section's facilities include a Control Data CYBER 171 Computer System, a Digital Equipment PDP-11/60 Minicomputer, a CALCOMP 925/1036 high-speed plotter and a data entry service.

The Section also provides technical support for the Wang Office Information System, which provides administrative word processing for NWRI and Ontario Region, Inland Waters Directorate.

**Future Requirements Planning.** The contract for the currently installed CDC CYBER 171 System has been extended through July 1986 to permit sufficient time to complete the procurement of a replacement system.

In the third quarter of 1984, a vendor survey was conducted to determine whether a competitive procurement of a new system was required. A letter of inquiry was sent to 47 vendors taken from the DSS Master List of large computer suppliers. In all, 16 vendors replied, two with a positive response. One was Control Data Canada, the present supplier, and the other was IBM Canada. It appears that a competitive procurement will be required.

The Treasury Board Submission requesting approval, in principle, for the acquisition of a new computer system and the accompanying make-or-buy analysis were completed in April 1985. The submission was approved by Treasury Board for approval in December 1985.

**Software Upgrades and Development.** No system software changes were made during the report period. Because the CYBER 171 has insufficient memory to support the current version of the NOS operating system, all software upgrades will have to wait until the new system is installed. The CYBER is currently running with operating system software that is at least three years out of date.

An electronic mail system for the CYBER 171 system was written. This has been particularly useful for communication between NWRI and field parties in the Montreal area. (*Pulley*)

On the PDP-11, application development by staff of the Data Management Section has continued. Digitizing and data editing applications are now operational, and a satellite imagery application is currently under development. Hardware problems with the digitizing table appear to have been resolved, and the Hydraulics Division has made extensive use of this device.

**Computer Operations.** CYBER system usage for the 1984/85 fiscal year was 2763 hours of central processor time. This represents a slight decrease from the previous year's total, 2777 hours. This absence of workload growth is the result of the departure of the Fisheries and Oceans Oceanography group from CCIW and the saturation of the CYBER system in the 8 a.m. to 5 p.m. prime shift period during much of the year.

The equivalent commercial value of services provided to CCIW amounted to \$1 000 000. Non-NWRI usage amounted to 19.9% of the total.

No CYBER 171 system downtime occurred in 1984/85. During the first half of 1985/86, three hours of downtime occurred, the result of problems with the chilled water supply to the central processor. Throughout the report period system availability exceeded 99%.

**Data Communications.** The Section has been involved in the design of the data transmission capabilities of the new telephone system. This involvement included participation in the CCIW team, which provided overall specifications for data requirements and design of the communications for the CYBER 171. The new telephone system will provide more shared ports and higher speeds for users at CCIW.

## STAFF LIST

Chief — J. Lawrence, B.Sc., Ph.D.

Secretary — J. Burford

A/Administrative Officer — J. Major

## Analytical Chemistry Research Section

### Head

I. Sekerka, B.Sc., electroanalytical chemistry  
C.Sc., RNDr. and flow injection analysis

### Researchers

P.D. Goulden, B.Sc., Ph.D., automation and atomic  
P. Eng. spectroscopy

F.I. Onuska, M.Sc., Ph.D., gas chromatography and  
P.Chem.Eng. GC/MS



B.F. Scott, B.Sc., Ph.D.,  
M.A. high pressure liquid  
chromatography,  
polarography, molecular  
fluorescence spectrometry

J.P. Sherry, B.Sc., Ph.D. mycology, radioimmunoassay

#### Technical Staff

J.F. Ryan  
R.J. Wilkinson  
J.R. Lechner  
D.H. Anthony, B.Sc.  
K.A. Terry

#### Microbiology Laboratories Section

##### Head

**B.J. Dutka, B.A., B.Sc.,  
M.Sc.** microbiological methods,  
toxicity screening

##### Researchers

S.S. Rao, B.Sc., Ph.D. acid stressed bacteria, lake  
microbiology

#### Technical Staff

A.A. Jurkovic  
K.K. Kwan, B.A.  
R. McInnis  
K. Jones, B.Sc.

#### Quality Assurance and Methods Section

##### Head

**A.S.Y. Chau, B.Sc.,  
M.Sc., FCIC, FIBA** reference materials, quality  
assurance

##### Researchers

V. Cheam, B.Sc., Ph.D. methods development  
(inorganic), quality control

H. Alkema, B.T. specification generation,  
interregional Q.C.,  
preservation

K.I. Aspila, B.Sc., M.Sc. quality assurance

H.B. Lee, B.Sc., Ph.D. quality assurance, standard  
reference materials, sample  
storage conditions, methods  
evaluation

Y. Stokker, B.Sc., M.Sc. organic method development,  
quality assurance

#### Technical Staff

N. Arafat, B.Sc.  
F. Gorrie  
P. Leishman, B.Sc.  
G. Dookhran

#### Computer Services Section

##### Head

**H.C. Pulley, B.Sc.** computer operations

M. Kinder computer operations

B. Malseed computer console operation

U. Hamilton computer console operation

J. Foley peripheral and keypunch  
operation

#### Clean and Hazardous Chemicals Laboratory

R.J. Wilkinson

## COMMITTEE MEMBERSHIP

#### K.I. Aspila

Chairman, Member, Surveillance Work Group of  
the IJC Water Quality Program Committee

Data Quality Work Group of the Surveillance Work  
Group, IJC

LRTAP Quality Assurance Subgroup, Federal-  
Provincial Committee on LRTAP

#### A.S.Y. Chau

General Referee, Committee H. Water  
Methodology, AOAC

Quality Assurance Committee, AOAC

Coordinator for Water and Sediment, FICP Check  
Sample Program, FICP

Ad Hoc Committee on the Review and Evaluation  
of the AOAC Journal

Chairman, Quality Management Work Group,  
Upper Great Lakes Connecting Channel Study

Research Board of Advisors, National Division,  
American Biographical Institute

Editorial Review Board, *Journal of Agricultural  
Food and Chemistry*

#### V. Cheam

Analytical Methods Work Group — LRTAP

#### B.J. Dutka

ASTM Subcommittee D19:24 — Resigned as  
Chairman in 1985

Joint Task Group, Section 907, Heterotrophic Plate  
Count, APHA Standard Methods

Joint Task Group Section 919, Rapid Detection  
Methods, APHA Standard Methods

Joint Task Group Section 914, Recreational  
Waters, APHA Standard Methods

Canada ISO/TC147/SC4, Microbiology —  
Chairman

ISO/TC147/SC4/WG9, Membranes — Chairman  
and International Secretariat

Canadian Task Group Chairman — Aerobic  
bacteria ISO/TC147/SC4/WG1

International Symposia on Toxicity Testing Using  
Bacteria Committee — Co-Chairman

Associate Editor, *Journal of Great Lakes Research*

Editorial Board, *WHO Water Quality Bulletin*

Microbial Problems Committee of the American  
Water Works Association

#### P.D. Goulden

Inland Waters Directorate Committee on Technical  
Training

Editorial Board, *WHO Water Quality Bulletin*

#### J. Lawrence

Great Lakes Toxic Chemicals Committee

RMCC Quality Assurance Sub-Group —  
Co-Chairman

Analytical Methods and Data Management Work Group — NWRI/Water Quality Branch Advisory Committee (Chairman)

International Organization of Legal Metrology (OIML) — Water Pollution Secretariat

Editorial Board, *WHO Water Quality Bulletin*

H.B. Lee

Associate Referee for Herbicides, Committee H, Water Methodology, AOAC

Associate Referee for Organo-phosphate, Committee E, Organo-phosphate, AOAC

F.I. Onuska

Editorial Review Board, *Journal of Analytical Chemistry*

Editorial Review Board, *Canadian Chemical News*

Advisory and Editorial Board, *High Resolution Chromatography and Chromatography Communications Journal*

H.C. Pulley

VIM (CDC Computer User's Group) Applications and Graphics Products Committee

S.S. Rao

ASTM Task Group D19:24:06:09 and D19:24:06:10 — Chairman

Advisory Committee, Masters Program, Department of Biology, University of Toronto (sponsored by Dr. A.P. Zimmerman)

Lake Huron Task Group Member

International Symposium on Microbial Ecology — Co-Chairman

## PUBLICATIONS

Analytical Methodology Working Group Final Report. 1985. A Report of the Ad Hoc Work Group on Analytical Methodology to the LRTAP Quality Assurance and Methods Subgroup of the Federal-Provincial Research Monitoring and Coordinating Committee.

**Aspila, K.I.** 1984. Preparation of interlaboratory study No. 48, total phosphorus in unpreserved sewage plant effluents. NWRI MS 111-AMD-6-84-KA.

**Aspila, K.I.** Final report of the data quality work to participants of IJC interlaboratory study No. 48, total phosphorus in sewage treatment plant effluents. NWRI MS. 119-AMD-6-84-KIA.

**Aspila, K.I., and S. Todd.** 1984. LRTAP intercomparison study L-5, major ions, nutrients and physical properties in water.

**Aspila, K.I., and S. Todd.** 1984. LRTAP intercomparison study L-6, major ions, nutrients and physical properties in water.

**Aspila, K.I., and S. Todd.** 1984. LRTAP intercomparison study L-7, trace metals in water.

**Aspila, K.I., and S. Todd.** 1985. LRTAP intercomparison study L-8, major ions, nutrients and physical properties in water.

**Aspila, K.I., G. Dookhran and P. Leishman.** 1985. LRTAP intercomparison study L-10, major ions, nutrients and physical properties in water.

**Aspila, K.I., G. Dookhran, P. Leishman and S. Todd.** 1985. LRTAP intercomparison study L-9, major ions, nutrients and physical properties in water.

**Aspila, K.I., R.E. White, and J.L. Clark.** 1985. Interlaboratory Quality Assurance Aspects of the International Joint Commission's Great Lakes Monitoring Programs. Quality Assurance for Environmental Measurements, ASTM STP 867. J.K. Taylor and T.W. Stanley (eds.), American Society for Testing and Materials, Philadelphia.

**Cheam, V., and A.S.Y. Chau.** 1984. Research and development of certified reference materials for toxic metals and major ions. Presented at the 27th Conference on Great Lakes Research, St. Catharines, April 30 – May 3, 1984.

**Cheam, V., and A.S.Y. Chau.** 1985. National interlaboratory quality control study No. 29, sodium, potassium, magnesium, calcium and hardness in natural and spiked water samples. Environment Canada, Inland Waters Directorate, Rep. Ser. No. 74, Burlington.

Dickman, M.D., **S.S. Rao**, and H.G. Thode. Effect of lake acidification on sediment bacteria, sediment diatom and sulphur isotope downcore profile. NWRI Rep. No. 85-87.

**Cheam, V., and A.S.Y. Chau.** Final summary report of the national study No. 33 — SO<sub>4</sub> in coloured waters. AMD Contribution No. 130, AMD-6-85-VC.

**Cheam, V., A.S.Y. Chau, and K.K. Kwan.** Preservation of physical parameters and major ions in waters. NWRI Contribution No. 85-112.

**Cheam, V., A.S.Y. Chau, and S. Todd.** Sulphate in coloured waters: Investigation on methodologies, data reliability and approaches for salvaging historical colorimetric data. NWRI Contribution No. 85-95.

**Dutka, B.J.** 1984. Biological toxicant screening activities within the Department of Environment's ECS and EPS. AMD Rep. No. 98-AMD-5-83-BJD.

**Dutka, B.J.** 1984. Sensitivity of *Legionella pneumophila* to sunlight in fresh and marine waters. Appl. Environ. Microbiol. 48: 970-974.

**Dutka, B.J., and K.K. Kwan.** 1984. Studies on a synthetic activated sludge toxicity screening procedure with comparison to three microbial toxicity tests. In *Toxicity Screening Procedures Using Bacterial Systems*, D. Liu and B.J. Dutka (eds.), Marcel Dekker Inc., New York and Basel, pp. 125-138.

**Dutka, B.J., and K.K. Kwan.** 1984. Study and long-term effects of oil and oil-dispersant mixtures on freshwater microbial populations in man-made ponds. Sci. Total Environ., 35: 135-148.

**Dutka, B.J., and K. Walsh.** 1984. Distribution patterns of *Legionella* bacteria within the Canadian Great Lakes. Abstract. XXVII Conference, IAGLR, Brock University, St. Catharines, Ontario, May 1-3.

**Dutka, B.J., and K. Walsh.** 1984. Studies on the longevity and growth patterns of *Legionella* under laboratory conditions. CCIW-IWD Report Series, MS 115-AMD-5-84-BJD.

**Dutka, B.J., and K. Walsh.** 1985. Preliminary evaluation of the coliphage technique in three Canadian rivers. NWRI Contribution No. 85-93.

**Dutka, B.J., and K. Walsh.** 1985. Preliminary evaluation of the coliphage technique in three Canadian rivers. NWRI Report No. 85-93.

**Dutka, B.J., K. Walsh, P. Ewan, and R.S. Tobin.** 1984. Incidence of *Legionella* organisms in Canadian environmental waters and water distribution systems, 1983-84 studies. Environment Canada, NWRI Contribution No. 84-13.

**Dutka, B.J., K. Walsh, P. Ewan, and R. Tobin.** 1985. Summary report of 1982-1984 studies on the incidence of *Legionella* organisms in (A) Canadian environmental waters and (B) water distribution systems within public and private buildings. NWRI Rep. No. 85-89.

**Dutka, B.J., K. Walsh, P. Ewan, A. El-Shaarawi, and R.S. Tobin.** 1983. Environmental distribution patterns of *Legionella* in central Canada and longevity studies. Environment Canada, NWRI Rep. No. 69-AMD-5-83-BJD.

**Dutka, B.J., K. Walsh, P. Ewan, A. El-Shaarawi, and R.S. Tobin.** 1984. Incidence of *Legionella* organisms in selected Ontario (Canada) cities. Sci. Total Environ., 39: 237-249.

**Goulden, P.D., and D.H.J. Anthony.** A method for the simultaneous determination of lead and tin at trace levels in environmental samples by continuous flow — hydride generation — ICAP analysis. Tech. Rep. AMD 85-05.

**Goulden, P.D., and D.H.J. Anthony.** Elemental analysis of organics and organometallic capillary gas chromatographic eluates using the microwave induced plasma and the inductively coupled argon plasma as excitation sources for detection. AMD Tech. Rep. 128-AMD-3-85-PDG.

**Goulden, P.D., and D.H.J. Anthony.** Design of a large-sample extractor for the determination of organics in water. NWRI Contribution No. 85-121.

**Goulden, P.D., D.H.J. Anthony, O. ElKei, and K.D. Austen.** Design and evolution of a continuous flow system with increased sample throughput for arsenic and selenium analysis by ICAP spectrometry. Tech. Transfer Rep. 118-AMD-3-84-PDG.

**Goulden, P.D., D.H.J. Anthony, O. ElKei, and K.D. Austen.** Determination of Ca, Mg, Na, K in precipitation samples by inductively coupled argon plasma — emission spectrometry. Tech. Transfer Rep. 85-02.

King, E.F., and **B.J. Dutka.** 1984. Respirometric technique. CCIW-IWD-AMD Rep. Ser. MS No. 108-AMD-5-84-BJD.

**Kwan, K.K.** 1985. Microbiological studies of the St. Lawrence River, 1984. NWRI, AMD Rep. Ser. No. 127-AMD-5-85-KKK.



- Kwan, K.K.** 1985. Microbiological studies of the Ottawa River. NWRI, AMD Rep. Ser. No. 126-AMD-5-85-KKK.
- Kwan, K.K., and B.J. Dutka.** 1985. Microbiological studies of Lake St. Louis sediments. AMD, NWRI Rep. No. 121-AMD-5-85-KKK.
- Kwan, K.K., B.J. Dutka, and K. Walsh.** 1985. Microbiological studies of Lake St. Louis sediments. NWRI, AMD Report No. 129-AMD-5-85-KKK.
- Kwan, K.K., B.J. Dutka, and K. Walsh.** 1985. Microbiological studies of the Fraser River. AMD, NWRI Rep. No. 129-AMD-5-85-KKK.
- Lawrence, J., F.I. Onuska, R. Wilkinson, and B.K. Afghan.** 1985. Methods research: determination of dioxins in fish and sediment. Presented at the 5th Int Symp. on Dioxins and Related Compounds, Bayreuth. Highlights.
- Lawrence, J., F. Onuska, R. Wilkinson, and B.K. Afghan.** Methods research: determination of dioxins in fish and sediment. Submitted to Ecol. Chem. Geochem.
- Lee, H.B., and A.S.Y. Chau.** 1984. Dredging quality control study No. 2 (DQC-2). Analysis of toxic trace metals in sediment. MS No. 105-AMD-6-84-HBL.
- Lee, H.B., and Y.D. Stokker.** 1985. Analysis of 11 triazines in natural waters. NWRI Contribution No. 85-114.
- Lee, H.B., G. Dookhran, and A.S.Y. Chau.** 1985. Dredging quality control study No. 3 (DQC-3). Analysis of PCBs in naturally contaminated dry sediments and standard solutions. MS No. 123-AMD-6-85-HBL.
- Lee, H.B., R.L. Hong-You, and A.S.Y. Chau.** 1985. Analysis of phenols by chemical derivatization. IV. Rapid and sensitive method for analysis of 21 chlorophenols by improved chloroacetylation procedure. JAOAC, 68: 422.
- Lee, H.B., R.L. Hong-You, and A.S.Y. Chau.** 1985. Analytical reference materials. Part V. Development of a sediment reference material for chlorobenzenes and hexachlorobutadiene. NWRI Contribution No. 85-92. The Analyst. In press.
- Lee, H.B., Y.D. Stokker, and A.S.Y. Chau.** 1985. Chemical derivatization analysis of pesticide residues. X. Analysis of ten acid herbicides in natural waters. NWRI Contribution No. 85-91.
- Lee, H.B., L.D. Weng, and A.S.Y. Chau.** 1984. Confirmation of pesticide residue identity. XI. Organophosphorus pesticides. JAOAC, 67: 553.
- Lee, H.B., L.D. Weng, and A.S.Y. Chau.** 1984. Chemical derivatization analysis of pesticide residues. VIII. Analysis of 15 chlorophenols in natural water by in-situ acetylation. JAOAC, 67: 789.
- Lee, H.B., L.D. Weng, and A.S.Y. Chau.** 1984. Chemical derivatization analysis of pesticide residues. IX. Analysis of phenol and 21 chlorinated phenols in natural waters by formation of pentafluorobenzyl ether derivatives. JAOAC, 67: 1086.
- McQueen, D.J., S.S. Rao, and D.R.S. Lean.** 1984. Hypolimnetic aeration: changes in bacterial populations and oxygen demand. Arch. Hydrobiol., 99: 498-514.
- Nagy, E., D.S. Painter, and B.F. Scott.** 1985. The fate and impact of 2,4-D on an aquatic ecosystem. Proc. 1st Int. Symp. on Water Milfoil, Vancouver, B.C., July 21, 1985, sponsored by the Aquatic Plant Management Society.
- Onuska, F.** 1985. Mass spectrometry of carbamates, thiocarbamates, dithiocarbamates, urea, thiourea and carboxanilide pesticides. In *Mass Spectrometry in Environmental Sciences*, F.W. Karasek, O. Hutzinger and S. Safe (eds.), Chapter 17, pp. 367-404.
- Onuska, F.** 1985. Mass spectrometry of chlorinated polycyclic hydrocarbon pesticides. In *Mass Spectrometry in Environmental Sciences*, F.W. Karasek, O. Hutzinger and S. Safe (eds.), Chapter 18, pp. 405-422.
- Onuska, F.** 1985. Determination of chlorinated benzenes in bottom sediments by WCOT column gas chromatography. Anal. Chem. 57: 801-805.
- Onuska, F.** 1985. Packed columns vs. WCOT columns in quantitative analyses of PCBs (with R.J. Kominar & K.A. Terry). J. High Resolut. Chromatogr. Chromatogr. Commun., 8: 747-754.
- Rao, S.S.** 1985. D-4454 — Standard test method for simultaneous enumeration of total and respiring bacteria in aquatic systems by microscopy. Annual Book of ASTM Standards.
- Rao, S.S.** 1985. D-4455 — Standard test method for enumeration of aquatic bacteria by epifluorescence microscopy counting procedures. Annual Book of ASTM Standards.
- Rao, S.S., A.A. Jurkovic, and B.J. Dutka.** 1984. Some factors influencing the enumeration of metabolizing aquatic bacteria. J. Test. Eval., 12: 56-59.
- Rao, S.S., A.A. Jurkovic, and J. Nriagu.** 1984. Bacterial activity in sediments of lakes receiving acid precipitation. Environ. Pollut. (Ser. A), 36: 195-205.
- Rao, S.S., D. Paulin, and G.G. Leppard.** 1984. Effects of low-pH stress on the morphology and activity of bacteria from lakes receiving acid precipitation. Hydrobiologia, 114: 115-121.
- Scott, B.F., and J.F. Ryan.** 1985. Analysis of toxaphene in fish tissue. CCIW unpub. MS.
- Scott, B.F., and J.F. Ryan.** 1985. Validation of toxaphene methodology for fish tissue. CCIW unpub. MS.
- Scott, B.F., E. Nagy, B.J. Dutka, J.P. Sherry, W.D. Taylor, U. Glooschenko, P.J. Wade, and J. Hart.** 1984. The fate and impact of oil and oil-dispersant mixtures in freshwater pond ecosystems: Introduction. Sci. Total Environ. 35: 105-113.
- Sekerka, I., J.F. Lechner, and G. Sardella.** Determination of Ca and Mg by flow injection analysis and atomic absorption spectroscopy.
- Sherry, J.P.** 1985. Temporal distribution of indicators (faecal coliforms and faecal streptococci) and opportunistic pathogens (*Candida albicans* and *Pseudomonas aeruginosa*) at a Lake Ontario bathing beach on high and low bather level days. NWRI Rep. No. 85-45.
- Sherry, J.P., and I. Sekerka.** 1984. Stability and preservation of iodide in natural water samples. NWRI Rep. Ser. No. 109-AMD-3-84-JPS.
- Stephenson, M., B.F. Scott, and G.L. Mackie.** Effects of 2,4-D treatment on pond benthos. I. Growth of pisidiid clams and bioaccumulation of 2,4-D and 2,4-DCP. Submitted for publication.



The Hydraulics Division undertakes research into all aspects of the hydraulics of inland waters and provides a multi-disciplined engineering capability in design, manufacture and maintenance of special equipment and measuring systems to support other inland water research teams.

National programs are undertaken in applied and basic research related to hydraulic, fluid mechanic, hydrologic, geophysics and geologic processes in fluvial, lacustrine and man-made environments.

### ENVIRONMENTAL HYDRAULICS SECTION

There are three main areas of research in the Environmental Hydraulics Section: river hydraulics, river ice engineering and urban water resources.

**River Diversions.** A review report on the effects of diversions on river regime has been completed. This report discusses the possible changes in the donor as well as the receiving streams which may occur as a result of the diversion of water from one stream to the other. Methods presently available for predicting these effects are outlined. Research required for improving the predictive capability is discussed. (Lau)

**Resistance for Flows with Rippled Beds.** Alluvial streams often have ripple formations on the river bottom. For calculations of flow level, the ripple characteristics must be known. In addition, for calculating sediment transport, the part of the total flow resistance that contributes toward bed material movement requires evaluation. A series of flume experiments using different sizes of material has been carried out to obtain such information. (Lau)

**Transverse Mixing under Ice Cover.** Data from field experiments in several river reaches under both ice-covered and open-water conditions have been analyzed to show that the dimensionless coefficient  $E_z/U.H$  is the same for ice covered and ice free flow. The data also showed that the mixing coefficient increased with sinuosity. (Lau)

**RIVMIX MK II: Users Manual.** RIVMIX MK II is a computer model capable of predicting the transverse spreading of a non-conservative pollutant released into a natural stream as a continuous steady source. This is an updated version of RIVMIX MK I which deals with the spreading of conservative substances. The Users Manual contains details of the model, input data arrangement and a listing of the computer program. (Krishnappan)

**Prediction of Sediment Sorting Using MOBED: Users Manual Update II.** The model MOBED was updated to include a sediment-sorting algorithm. With this algorithm, the model is now capable of predicting the size distribution of the bed sediment as a function of time and distance along the river in addition to predicting the usual water and bed level changes and other hydraulic and sediment transport characteristics. The details of the algorithm and the changes that resulted to the source code and input data arrangements as a result of the inclusion of the algorithm are described in a users manual update. (Krishnappan)

**Modelling of Flood Plain Flows.** A turbulence model has been developed to predict the three-dimensional velocity distribution and the distribution of shear stress around the wetted perimeter of compound channels consisting of a main channel and wider, shallower flood plains. The model predictions were compared with published data for the total discharge at a given flow depth, the division of flow between main channel and flood plain sections as well as the shear stress distribution around the wetted perimeter. (Krishnappan, Lau)

**Resistance of Sand Waves in Reversing Flows.** At the request of Water Resources Branch, Pacific and Yukon Region, a study is being conducted to investigate the flow resistance in the Pitt River, a tributary of the Fraser, when tidal effects give rise to flows in different directions over the sand waves. The tests are conducted in the 1-m flume using artificial bedforms. (Lau)

**Application of MOBED to the Qu'Appelle River between Craven and Pasqua Lakes.** The model MOBED was applied to the Qu'Appelle River between Craven and Pasqua lakes to test the effectiveness of the channel conveyance improvement scheme proposed by the Saskatchewan Water Corporation. The proposal involves several meander loop cutoffs and dredging of the existing channel at several reaches at an estimated cost of 4.5 million dollars. The model predictions (Fig. 22) indicate significant bed level changes with degradation in the upstream reaches and aggradation in the downstream reaches near the lake. (Krishnappan)

**Flathead River International Study Board: Water Quality and Quantity Technical Committee.** Contribution to the baseline data report on the water quality and quantity of the Flathead River in the upper basin was made as part of the impact assessment of the proposed coal mine development near Cabin and Howell creeks in British Columbia. (Krishnappan)

**Effects of Relative Flow Depth in Physical Models of Sediment Transport in Uni-directional Flows.** Experiments in the 2-m flume were carried out to establish the scale effects in physical models dealing with sediment transport in river flows. A paper describing the experimental procedure and results has been submitted to the IAHR symposium on scale effects in modelling sediment transport to be held in Toronto in 1986. (Krishnappan, Engel)

**CSCE Task Group on River Models.** At the request of the Research Committee of the Hydrotechnical Division of the Canadian Society of Civil Engineers, a task group was initiated, chaired by B.G. Krishnappan, to evaluate the existing (public domain) river flow models. A total of 12 models dealing with both steady and unsteady flows in rigid and mobile boundary channels were selected and will be evaluated by applying them to identical data sets. (Krishnappan)

**Migration Speed of Dunes.** Different methods of computing dune speed from bed profile records as well as the geometric characteristics of dunes are being investigated using experiments in the 2-m flume. The migration speeds of dunes are useful for the computation of bed load discharge in large rivers, whereas bed form heights and lengths provide information

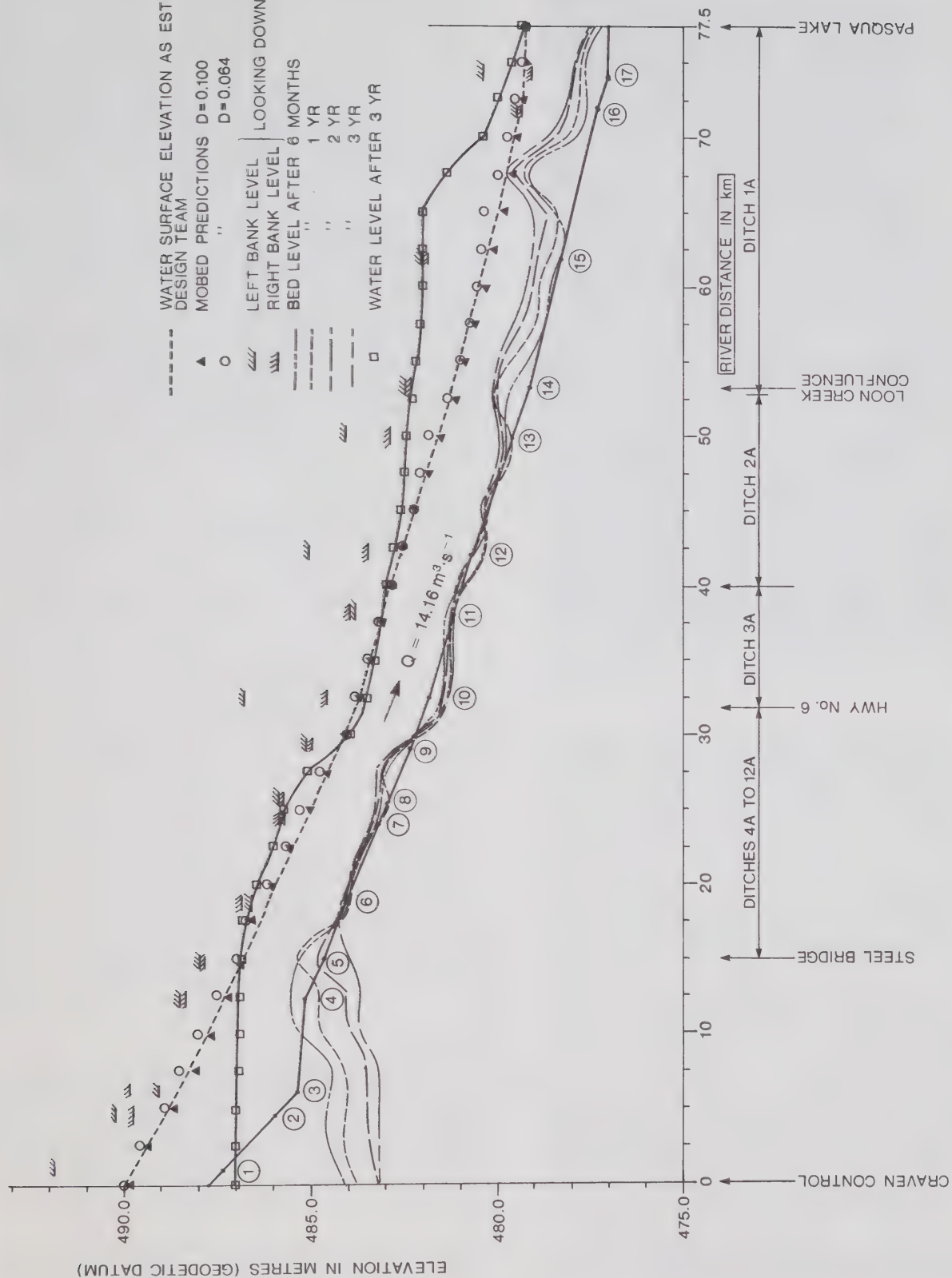


Figure 22. Variation of bed levels as predicted by MOBED for the Qu'Appelle River reach between Craven and Pasqua lakes.



concerning flow resistance and changes in bed elevation of navigation channels. A typical dune bed in a large sediment flume is shown in Figure 23. (Engel)



Figure 23. Dune bed in large sediment flume.

**Hydraulic Efficiency of Bed Load Samplers.** Studying the hydraulic efficiency enables more accurate estimates of local sediment transport. Tests in the 2-m flume are used to obtain the efficiency of the basket and the Helley Smith samplers, and to determine calibration curves. (Engel)

**Performance Characteristics of Current Meters.** Experiments were conducted in the towing tank at the National Water Research Institute to investigate the effect of the 15-lb, 30-lb, 50-lb and 100-lb Columbus type sounding weights on the performance of the Price 622AA current meter when used with the WR2 hangar. The analysis showed that a meter should be used with the same suspension configuration for which it is calibrated. Failure to do so may cause errors of several percent at some speeds but always in excess of  $\pm 0.5\%$  at virtually all speeds. (Engel)

**Development of Current Meter Rotors.** A plastic rotor design has been successfully modified to improve performance. Preliminary tests have indicated that a reduction in threshold speed from 4 to 2 cm/s can be achieved, which is important for low flow measurements. The final design will be supplied to the Water Survey of Canada for future production. (Engel)

**Evaluation of Water Level Recording Systems.** The performance characteristics of float type and gas-purge type sensors, pressure transducers and satellite platforms are being

systematically evaluated in the laboratory. The results will go to Water Survey of Canada to provide baseline information for the updating of water level recording instrumentation. (Engel)

**Field Studies of River Ice Jams and Flooding.** This is a long-term field observation program, initiated in 1979. Emphasis is on collection of quantitative data needed to address deterministic and statistical aspects of river ice breakup and jamming. Freeze-up and winter conditions are also documented, as they have been found to influence the breakup process. Observations were carried out in the Thames and Grand rivers, Ontario. In the Thames River, serious flooding occurred because of an ice jam near Prairie Siding. Contact and cooperation with other agencies interested in jamming problems have been maintained and expanded. (Beltaos)

**Theoretical Studies of Ice Jams.** Field documentation continues to be obtained for a recently developed conceptual model of ice breakup and a dimensionless expression of equilibrium jam stage. Important aspects of ice jamming phenomena are the conditions at the toe (downstream end) that influence the stability of the jam and thence the peak water levels. A mathematical model has been developed to predict the characteristics of the downstream transition of equilibrium jams (Fig. 24). The model utilizes the granular-mass theory of ice jams as well as seepage and hydraulic resistance equations. Reports are available from the Hydraulics Division. (Beltaos)

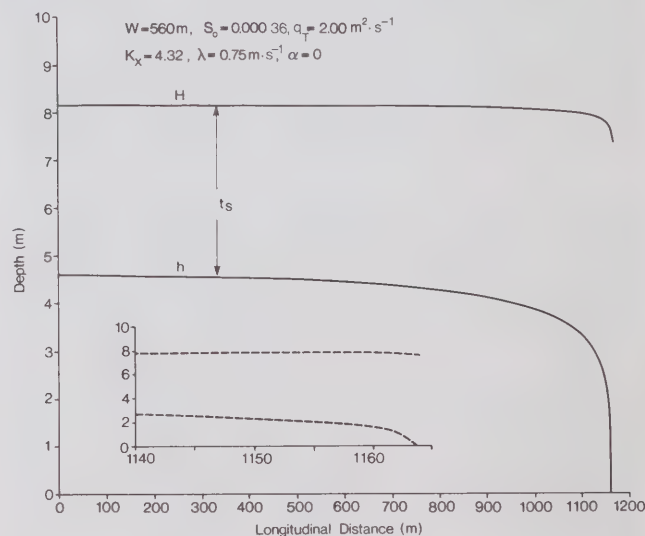


Figure 24. Example of computed ice jam profile for typical conditions in the Athabasca River near Fort McMurray. Insert shows profile in the vicinity of grounding, plotted without distortion.

**Advice to Inland Waters Directorate, Atlantic Region.** Advice on ice-related hydrotechnical problems continues to be provided to IWD, Atlantic Region. The Canada-N.F. FDRP hydrotechnical study on the Exploits River at Badger, Newfoundland, was completed in 1984/85, and a similar study on the Rushoon River at Rushoon is expected to be completed in FY 1985/86.

**Laboratory Studies of Ice Jams.** Tests with plastic blocks have indicated two mechanisms of grounding of ice jams forming at the upstream edge of an intact ice cover: (a) when the



size of submerging blocks exceeds the available water depth, as has been reported by others in the past and (b) when a surface accumulation of ice blocks collapses, leading to a "snowballing" process and formation of very thick jams.

The interaction between an ice jam and a breakable ice cover is an important question that cannot be solved in the laboratory using blocks and sheets of plastic to simulate ice. Work has been in progress to develop an ice-substitute material that, at room temperature, would have appropriately scaled down strength properties. (*Beltaos*)

**Working Group on River Ice Jams.** The National Research Council of Canada has formed a Working Group on River Ice Jams, chaired by Dr. S. Beltaos. Work is nearly completed on the Group's four initial tasks, i.e., guidelines for field data collection programs; guidelines for extracting ice breakup data from hydrometric station records; identification of research needs; and compilation of case studies. The Group's term has recently been extended by two years to prepare a monograph on ice jams.

**Frazil and Anchor Ice.** A cooperative field study with Hydro-Québec to study the frazil and anchor ice in the Lachine Rapids near Montreal and their hydraulic effect was conducted in the winter of 1984/85. The field study was to assist Hydro-Québec's Archipel Project, which is the construction of a low head power station at the rapids.

A photographic study on crystallographic evaluation of frazil crystals was completed.

The data on the frazil effect on water flow in the Beauharnois Canal collected in the winter of 1983/84 are now completed.

The laboratory setup for studying the hydraulic effect of frazil formation in flowing water is nearing completion. (*Tsang*)

**Modelling Runoff Transport in Drainage Networks.** Investigations were undertaken under the sponsorship of the Ontario Ministry of Transport and Communications to complement previous studies by focussing on special structures not investigated earlier. The results of these and earlier investigations were implemented by MTC in their design procedures. The testing of these procedures by MTC indicates that these savings could reach almost 3 million dollars annually depending on the level of road construction activities.

Other poorly understood aspects of runoff transport are the head losses at channel and conduit junctions. Recognizing the importance of junction head losses, the American Public Works Association, through its Ontario chapter, approached the Institute with a request for joint study of junction head losses and provided most of the study funds. Two types of junctions have been studied: T-junctions of a main with a perpendicular lateral and T-junctions of two opposed laterals and a single outfall. In these investigations, a new junction design that reduces typical losses by more than one half was developed.

**Waterford River Basin.** Effects of urbanization on water resources in the Waterford River Basin (Newfoundland) have been studied for several years in cooperation with several federal and provincial agencies. In the first phase of this study, urban runoff processes in fully sewered areas of the Basin were investigated. The study results include the characterization of runoff quantity and quality in the study area, detailed recommendations for the modelling of runoff and model selection, and recommendations of policies and measures to be implemented in future urban developments. Such policies and measures would reduce adverse effects of urbanization and reduce the costs of any abatement measures.

In the second phase of the study, the modelling of streamflow for the entire basin has been initiated using the Hydrologic Simulation Program — Fortran (HSPF) model. The results of the second phase will indicate the impact of progressing urbanization on flows in the Waterford River. (*Marsalek*)

**Pollutants in Urban Runoff.** Further studies of pollutant sources and their transport were undertaken in two Burlington test catchments. These studies addressed the problems connected with both the conventional and the toxic pollutants.

An evaluation of the rainwater contribution to urban runoff quality was carried out using data from the Blair Road site. It showed that a significant portion of certain pollutants was derived from rainwater and not from the land. Some field data showing the rainwater and runoff pollutant loadings are shown in Figure 25. (*Ng*)

Using the field data on persistent toxic substances in urban runoff, estimates of annual loadings of toxics transported by urban runoff in the Canadian Great Lakes Basin were prepared. These loadings confirm the earlier International Joint Commission finding that urban land runoff belongs to the major sources of toxics in the Great Lakes Basin. Four groups of toxic pollutants were studied: trace elements, polyaromatic hydrocarbons, PCBs, and organochlorine pesticides. Among these groups, trace elements contributed the highest loadings. In particular, the annual loadings of zinc and lead were almost 300 t·yr<sup>-1</sup> and 100 t·yr<sup>-1</sup>, respectively. (*Marsalek*)

**NATO Workshop on Urban Runoff Pollution.** This workshop, funded by NATO, was held in Montpellier, France, from August 26 to 30, 1985, with J. Marsalek serving as the program director. The workshop provided a discussion forum for about 40 invited leading experts from 14 countries. Workshop activities produced state of the art reviews on and future research directions for such discussion subjects as sources of pollution in urban runoff, toxic substances in urban runoff, modelling of runoff quality and impacts on receiving waters, and runoff quality control and management. The final workshop proceedings will be published in early 1986. (*Marsalek*)

**Support of UNESCO Activities under the International Hydrological Program (IHP).** In support of the UNESCO activities under the IHP, final drafts of four chapters for two UNESCO manuals on urban drainage design and acquisition of supporting data have been prepared and submitted to UNESCO. These chapters cover urban drainage design parameters, drainage hydraulics, collection of urban hydrological data, and organization of data collection programs. When published in 1986, the UNESCO manuals will provide authoritative and comprehensive guidance for urban drainage design, with a special reference to the conditions in less developed countries. (*Marsalek*)

**Toxic Contaminants in Urban Runoff Draining into the Upper Great Lakes Connecting Channels (UGLCC).** Evaluation of loadings of toxic contaminants in urban runoff draining into the Upper Great Lakes Connecting Channels has been initiated. Toward this end, field sites for the monitoring of toxics in runoff have been established in Windsor and Sarnia, and additional sites will be selected in Sault Ste. Marie. Runoff samples have been collected in storm sewers as well as at combined sewer outfalls. Collected samples are analyzed for four groups of persistent toxic substances: PCBs, organochlorine pesticides, polyaromatic hydrocarbons, and toxic inorganics. Field data will be used in conjunction with computer simulations to produce monthly loadings of toxic substances in runoff discharges. Such loadings will then form one of the

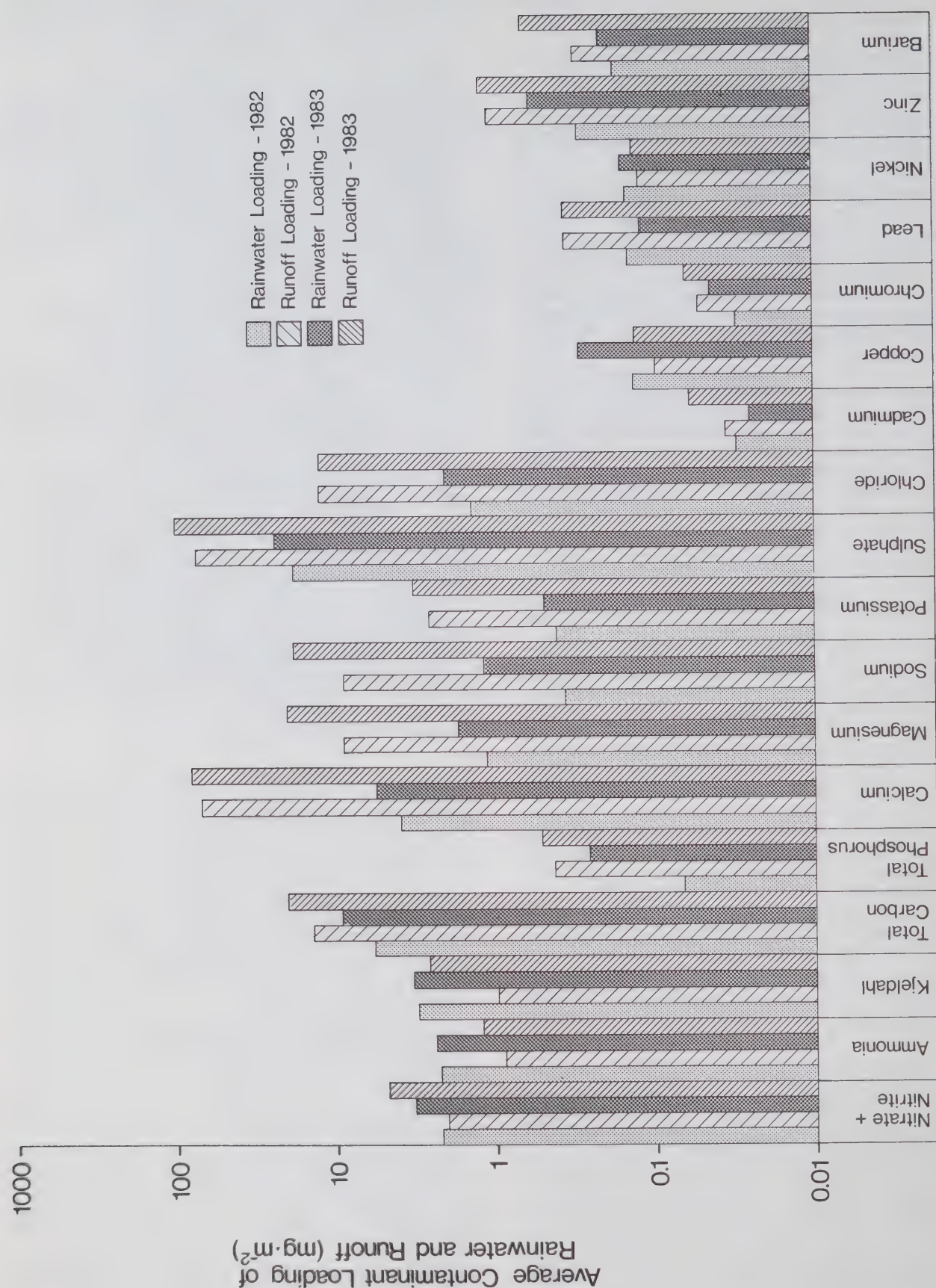


Figure 25. Rainwater and runoff pollutant loadings.



inputs to the inventories of toxics in the Upper Great Lakes Connecting Channels. (*Marsalek*)

## SHORE PROCESSES SECTION

The work of the Shore Processes Section is concentrated in three areas: air-water interaction, conservation and development; littoral and fluvial sedimentology; and geotechnique.

**Turbulent Mixing beneath Wind-Generated Waves.** A field experiment has been designed to measure some aspects of the interaction between wind-generated waves and turbulence in the wind-driven surface layer. The experiment, to take place in three phases over three years, is being conducted from the National Water Research Institute's offshore tower in Lake Ontario by scientists from both NWRI and the Woods Hole Oceanographic Institution. (*Donelan*)

**Wave Attenuation.** A laboratory experiment was conducted in the 100-m wind-wave flume to measure the direct attenuation of waves in an opposing wind. The resulting attenuation rates were substantial even when the wave slope was gentle (2.5%). These data will significantly influence the future development of wave generation theories. (*Donelan*)

**Remote Sensing of Winds.** A composite divided scale model for radar backscatter from the ocean surface was constructed to meet the needs of scatterometry, i.e., the remote sensing of surface winds using microwave radar. The primary scattering mechanism was taken to be Bragg scattering and an equilibrium wave number spectrum was derived on the assumption that the short wave energy density reflects a balance between direct wind forcing and dissipation due to breaking and to viscosity. The effects of tilt and modulation of the short waves by longer waves were included, and the model tests against aircraft scatterometer data with very encouraging results. At low wind speeds, scatterometry was found to be sensitive to surface water temperature because of dissipation of short waves changes with viscosity. For high wind speeds the measurements are less sensitive to water temperature. (*Donelan*)

**Wave Direction Movements for the Canadian Coastal Sediment Study.** The CCIW Wave Direction Buoy was deployed off Stanhope Lane, P.E.I., in support of the Canadian Coastal Sediment Study (sponsored by the National Research Council Associate Committee for Shoreline Erosion and Sedimentation). Wind and directional wave data were collected from late September to early November 1984, and a data report prepared. (*Skafel*)

**Floating Tire Breakwater Research.** Mooring load and wave transmission design information, substantiated by field measurements, was presented at a Floating Tire Breakwater Workshop held November 7-8, 1984, in Niagara Falls, New York. The Workshop was co-sponsored by the National Water Research Institute and the U.S. Army Engineer Waterways Experiment Station (WES). Workshop proceedings will be available from WES.

Advice on floating tire breakwaters was given to the Small Craft Harbours Branch, Ontario Region, for locations at Kingston and Belleville. (*Bishop*)

**Wave Prediction.** A two-dimensional lake wave prediction system developed at the Great Lakes Environmental Re-

search Laboratory in Ann Arbor, Michigan, was acquired and made operational at NWRI. The computer model uses methods developed at NWRI by M.A. Donelan to obtain reliable estimates of wave height, period and direction. (*Bishop*)

**Caisson Retained Artificial Islands.** A study was undertaken under contract to investigate the modelling of overtopping volumes for caisson retained artificial islands. Modelled overtopping volumes were found to be too large by factors of 2 to 6. Also, spray distribution differed spatially from the prototype. Reasons for these discrepancies were explored; they include the effects of testing with unidirectional (long-crested waves), possible differences in wave groupiness, and shortcomings in the prototype data and analysis. (*Skafel*)

**Port Granby Waste Management.** A review was prepared for EPS, Ontario Region, of a report on bluff stability and monitoring of the Port Granby Waste Management Area. (*Zeman*)

**Waste Disposal Sites in the Coastal Zone.** Evaluation of the potential hazards of these sites has been carried out on the basis of proximity to the shoreline, local recession rate, subsurface hydrogeology and the nature of the wastes dumped at the sites (Fig. 26). (*Coakley*)

**Sediment Erodibility.** A procedure has been developed to make quantitative measurements of the erosion resistance of cohesive sediment using a rotating cylinder apparatus. The erodibility of two Lake Erie tills, not obviously different based on geotechnical tests, was determined. (*Zeman*)

**Coastal Evolution.** Planning of shore developments requires knowledge to differentiate recession trends that are modern (to a large degree related to cultural activities) from those that are related to natural long-term evolution. A comprehensive study of Lake Erie was concluded in 1984. (*Coakley*)

**Bottom Shear Stress and Erosion Relationship, Lake Ontario.** A site on the south shore of Lake Ontario at Stoney Creek was selected for a study of the rates and processes of underwater erosion of exposed glacial sediment on the near-shore slope. This is the most common type of substrate in shallow water in the lower Great Lakes, and its erosion has an effect both on the recession of the adjacent shore bluff and on the supply of sediment to the lake. The shear forces caused by waves acting on the bottom of the near-shore zone are important factors in coastal erosion rates. These forces are presently being evaluated at the test site. Waves were measured at regular intervals during the period October-December 1984, and the wave records are presently being analyzed to assess shear forces at the sediment-water interface. A relationship between the shear and the erosion will be tested. (*Coakley*)

Frames with fixed-transducers were reinstalled at five stations along the profile line at Stoney Creek, and bottom elevation was monitored acoustically and with diver measurements from April to December 1985. Changes from the December data of 1984 were noted in the inshore stations where a sand cover was present, but offshore elevations in the area of exposed till were the same as those previously recorded. (*Rukavina*)

**Erodibility of Cohesive Sediments.** Erodibility tests on till cores from the Stoney Creek site, including geotechnical tests, have been completed and results have been analyzed. New samples of Lake Erie fine-grained tills have been obtained for



## Lake Ontario Waste Sites

Active Sites : 11

Abandoned : 136

Total : 147



Figure 26. Plot of all waste disposal sites within 5 km of the Lake Ontario shoreline. Plot includes active and closed sites (courtesy of Ontario Ministry of the Environment Waste Disposal Management Branch).

erodibility tests of remolded sediments. A compaction mold, which is to be used for the preparation of remolded samples, is being built. The existing erodibility apparatus has been calibrated for the effect of surface roughness. (Zeman)

### Sediment/Contaminant Dynamics, Toronto Waterfront.

The transport of contaminated sediments from various point sources on the Toronto waterfront may pose a health hazard for local bathing beaches and water intakes. Studies to determine the directional patterns and, possibly, the rate of such transport are now underway (in cooperation with Environmental Contaminants Division and the Ontario Ministry of the Environment). Bottom samples collected in the Humber Bay and Eastern Beaches are being analyzed for grain size and major and trace elements, with a view to identifying potential natural tracers. Concurrent investigations are progressing into artificial means of tracing the transport of fine-grained sediments, which are recognized as major vehicles for adsorbed contaminants. (Coakley)

**Symposium on Cohesive Shores.** Preparations have started for a symposium on scientific and engineering research of rapidly eroding shores consisting predominantly of cohesive sediments. The symposium, sponsored by the NRCC Associate Committee for Research on Shoreline Ero-

sion and Sedimentation, will be held in Burlington in May 1986. (Zeman)

### Coastal Sediment Budget, North-Central Shore of Lake Erie.

Data from the 1979 study of the north-central shore of Lake Erie have been used to develop a coastal sediment budget for the area which examines the long- and short-term changes in coastal erosion and sedimentation and the influence of harbour structures. Results have been reported in a paper submitted to the *Journal of Great Lakes Research*. (Rukavina, Zeman)

**Van Wagners Beach Study.** All sounding records of Profile 18 at Van Wagners Beach have been digitized at points where fixed-transducer data or diver measurements are available. Results for the period 1980–82 are now being analyzed to determine the effects of storms and seasonal water-level changes on the profile form. (Rukavina)

**Lac Saint-Louis Bottom-Sediment Survey.** A survey of the sedimentology and bathymetry of Lac Saint-Louis in the St. Lawrence River was carried out at the request of Inland Waters Directorate, Quebec Region, which is investigating the pollution of the St. Lawrence. Field work was carried out in cooperation with IWD, Quebec Region, and the Quebec Region of the Canadian Hydrographic Service. (Rukavina)

**Great Lakes Near-Shore Sediment Data.** Near-shore file data have been requested by the Environmental Protection Service, Toronto (dredge spoil sites, Sarnia and Owen Sound; PCB Study, Wheatley), Huntco Toronto (geophysical equipment trials, Toronto area), and the city of Port Colborne (local planning). Lake Ontario near-shore data were used in conjunction with lake basin data to select sites for the IJC Lake Ontario Surveillance Program. A description of the near-shore data base was provided to the Ontario Sediment Survey Program Review at the request of WRB. Poster presentations on the structure and contents of the data base were made at the Great Lakes Conference in Milwaukee and the Canadian Coastal Conference in St. John's, Newfoundland. (*Rukavina*)

**Lake St. Clair Bottom Sediments (UGLCC).** Work has begun on the compilation of data on the bottom sediments of Lake St. Clair in support of the UGLCC program and assistance has been provided to the Aquatic Physics and Systems Division in the use of echo-sounding as a means of measuring the thickness of modern basin muds. (*Rukavina*)

**CCIW Open House, 1985.** Two of the displays presented at the Open House in April were a videotape presentation on beach changes and a computer quiz on shoreline facts and issues. (*Rukavina*)

An interactive display featuring the postglacial evolution of the Great Lakes in computer graphics was presented. (*Coakley*)

**Waves and Wave Forecasting.** A section on waves and wave forecasting has been written for a new Handbook of Civil Engineering to be published in 1986. Topics include small amplitude wave theory, wave processes, wave measurement techniques, analysis of wave data, wave statistics and confidence limits, and wave prediction methods. (*Bishop, Donelan*)

**Wave Attenuation by Rough Walls.** Experiments have been conducted in a wave flume to investigate the scale effects of modelling wave attenuation by lining harbour entrances with riprap. Placing rubble at side slopes of 1.5 or 2 to 1 on vertical entrance channel walls is a technique used more and more to correct wave agitation problems in harbours and/or to correct structural problems at the walls. Wave height attenuation was found to be proportional to the wave height raised to the power 1.36, and was found to be inversely proportional to the water depth ( $d$ ) raised to the power 0.36 and to the channel bottom width ( $w$ ). The proportionality factor was found to vary with  $d/gT^2$   $w/d$  and side slope (where  $T$  is the wave period and  $g$  is the accumulation due to gravity). (*Bishop*)

**Measuring Waves with Pressure Transducers.** Experiments to establish the veracity of linear wave theory to predict wave heights from subsurface pressures were completed. (*Bishop*)

**Wave Loads on Submarine Pipelines.** Wave loads on submarine pipelines are normally predicted using the Morrison equation, which uses empirically determined drag and inertia coefficients. Values that should be assigned to those coefficients remain very uncertain. In northern locations, where pipelines may be laid in open trenches to avoid ice damage, little or no data exist. A series of laboratory tests are being done to determine the drag, inertia, and lift coefficients for pipelines in trenches. Details of the flow field were also examined. This work is partially funded by the Panel on Energy Research and Development. (*Skafel*)

## TECHNICAL SERVICES SECTION

**Scientific Support Unit.** Technical staff provide support to scientists and engineers conducting basic and applied research in the Hydraulics Laboratory and related field projects.

A marked increase of field support was provided for the frazil, anchor ice, ice jams and flood studies. Support was also provided to third parties under the Department's cost recovery policy.

Tests to determine the head loss through various components of an automatic sediment sampler were done for the Water Survey of Canada.

**Geotechnical/Sedimentological Laboratory Services.** The sedimentology laboratory classifies sediments by their particle size and determines organic and total carbon in sediments. The geotechnical laboratory undertakes tests of soils as a structural material. These laboratories provide support for Institute projects as well as other government agencies, universities and the private sector. Cost recovery is used.

A new sedigraph was purchased which will be computerized to provide a more accurate and efficient service; modifications have also been made to the settling tube.

A summary of tests and analyses performed follows.

Tests and analyses	1984/85	1985/86
Particle size analysis		
NWRI	1105	1471
Universities	56	150
Private sector	31	53
Carbon analysis		
NWRI	242	4050
Sediment separation		
NWRI	47	76
Geotechnical tests		
NWRI	10	7

**Laboratory Operations Unit.** Users of the laboratory receive support such as carpentry, machining and equipment maintenance, and the supervision of outside contractors working in the laboratory. Consultations with scientists and engineers on construction problems, the inventory and procurement of materials and supplies were also undertaken. Advice on equipment and facility design, as well as on electronics and mechanics to the many users of the Hydraulics Laboratory, was provided by a group of highly qualified technologists.

A laminar flow flume was constructed for studies on meander formation and a frazil ice flume was constructed for laboratory testing of the frazil ice instrument.

**National Calibration Service.** The tow carriage microcomputer data acquisition system has now been in daily operation for over two years. A more powerful 16-bit computer has been procured to improve operations.

A very high accuracy calibration program for Hydro-Québec was completed under a cost recovery agreement involving the calibration of 65 SIAP current meters which will be used for turbine efficiency measurements. This special calibration required 48 different velocities and 12- to 14-hour days to complete the run.

At the request of Sediment Survey Section, Water Survey of Canada, plans were prepared to have Water Survey of Canada's entire inventory of suspended sediment samplers checked, repaired and calibrated. This work will be completed over a two-year period, after which each sampler will be recalled for recalibration every two years.



The use of the towing tank to calibrate current meters and to perform special tests on hydrometric equipment can be broken down as follows:

	Percent time used
Water Survey of Canada	35.1
Other federal agencies	25.3
Provincial governments	14.9
Universities	5.9
Hydro companies	8.4
Consulting engineering firms	10.4

## ENGINEERING SERVICES SECTION

**Volume Weighted Sampler.** The study of contaminant pathways and fates by Environmental Contaminants Division involves the collection of water samples weighted on the basis of the depth and shape of the water body. A portable Volume

Weighted Sampler System has been developed to automate this process for field teams.

A transport case (Fig. 27) contains a small keyboard with display, a microprocessor controlling a sequencing valve and a battery powered pump. The sampler is designed to work with a portable electrobathythermograph (EBT) as primary sensor input. The operator uses the keyboard to input the depth versus weighting characteristic desired for the sample to program the microprocessor controlling the pump and valve operating sequences. The sampling orifice is mounted on the EBT. At the completion of the EBT profile, the sample collected is integrated and volume weighted against depth and shape of the lake or pond. (*Desrosiers*)

**Suspended Sediment Sensor Study.** Sedimentologists and coastal engineers have a continuing requirement to measure the mass concentration of bed load and suspended material in streams and coastal zones. Acoustic rapid measurement is not yet possible. Engineering research is underway to find a way to monitor suspended solids reliably. (*Desrosiers*)

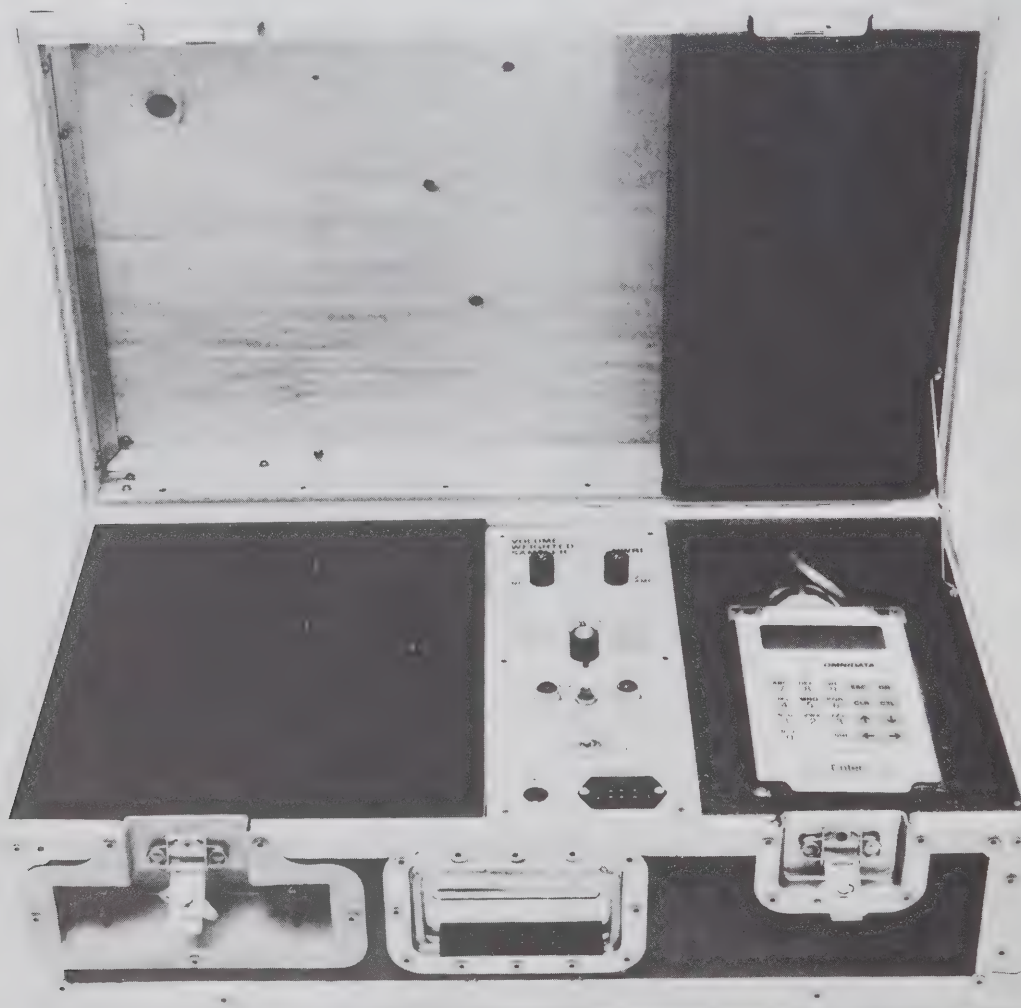


Figure 27. Volume weighted sampler.



**Under-Ice Drifter Buoy.** A program by the Aquatic Physics and Systems Division to study currents and mixing in northern lakes required a Lagrangian drifter buoy to operate under an ice cover in order to observe advective currents of low order, i.e., less than  $1 \text{ cm} \cdot \text{s}^{-1}$ . Besides being easily transportable and able to operate at  $-30^\circ\text{C}$ , the buoy can be deployed and retrieved through the ice, and its location can be fixed within a 50-cm circle of error under the ice cover using fish-tracking radio tag techniques. The system has been used on Tagish Lake, Y.T., with good results. (Roy, Savile)

**Frazil Ice Recorder.** Frazil ice formation in river and stream channels influences the conveyance of the channel. Knowledge of frazil ice formation may provide information for the prediction of restriction in winter flows and probability of flooding. In response to a requirement of the New Brunswick River Ice Sub-committee, NWRI has undertaken the development of a frazil ice recorder. A prototype system has been constructed and tests in an icing flume have confirmed the operating principle. Development work is continuing on the prototype toward field trials in the Nashwaak River, near Fredericton, New Brunswick. (Ford)

**Cytometer Development.** Researchers require additional data to obtain a more accurate assessment of biomass and biocontamination. Automation of the process of cell counting and classification would reduce the cost of obtaining this type of biological data.

Flow cytometry appears to be an attractive supplement to traditional microscopy. The literature and commercial systems were reviewed. It was concluded that commercial systems would be too expensive at this time to be justified by most laboratories. A "home built" system was proposed and some of the system components were enumerated. (Desrosiers)

**Program for Industry-Laboratory Projects (PILP).** PILP is the interdepartmental program for stimulating and financially assisting the transfer of technology from federal government research laboratories to Canadian industry for commercial exploitation. PILP activities at NWRI are coordinated by the Engineering Services Section. Equipment for which Contribution Arrangements are now in effect are the frazil ice sensor (Arctec Canada Ltd.), the solid state temperature logger (Metrex Instruments Ltd.), and the lightweight corer (Quest Engineering Ltd.). Another potential transfer being discussed with industry is the NWRI Wave/Wind Direction Buoy. (Roy, Ford, Desrosiers)

**Solid State Logger.** Long-term temperature records are essential for environmental studies. The NWRI Scientific Equipment Development Working Group (SEDWG) decided to develop a single-channel temperature logger using solid state storage devices and microprocessor technology. A unit logger could be a building block in arrays of temperature measurements. Much greater operational flexibility would be possible.

A prototype logger has been designed and constructed. This unit was field-tested and found satisfactory. A contract for the manufacture of five evaluation units of the solid state logger has been completed, and the long-term accuracy and reliability of the design will be evaluated by further field use. The contracting supplier has since received assistance under PILP to transfer this technology from NWRI to their product line. (Ford)

**ICAP Improvements.** The Inductively Coupled Argon Plasma (ICAP) spectrometer has been in use for a number of years by NWRI and the Water Quality Branch. Dr. P. Goulden of the Analytical Methods Division proposed a concept for

dynamic background correction to increase the sensitivity of this spectrometer. In response to a SEDWG request, Engineering Services has designed and installed a modification kit comprising a rotating chopper wheel and associated synchronous detector-preamplifier circuits for 24 spectrometer channels.

This modification has been demonstrated to provide a three-fold reduction in system noise over a short-term integration, which represents significant increase in system sensitivity. A report entitled "Dynamic Background Correction of an ICP Spectrometer" is in preparation. (Desrosiers)

## MANUFACTURING AND TECHNICAL DEVELOPMENT SECTION

The Manufacturing and Technical Development Section (MANTEC) provides technical services in support of scientific and engineering research studies. In fiscal years 1984-86, MANTEC supported a total of 128 studies, of which 114 were in support of NWRI and 14 were in support of non-NWRI studies. The following highlights some equipment and systems developed during these fiscal years. More detailed information of this equipment is contained in various equipment handbooks available from the Section. Other equipment developed by the Section is reported by the Engineering Services Section and other NWRI and non-NWRI clients.

**Snow Corer.** A new box corer for sampling snow was designed and built for the Turkey Lakes project. The corer is designed to take a  $250 \text{ cm}^2$  sample up to 1.2 m long. It is capable of handling snow consistencies ranging from soft and fluffy to firm and containing ice layers. The construction is of type 304 stainless steel. It is equipped with a driver so that it can be hammered into packed or icy material. The front cover can be slid back to enable study of the snow structure or subsampling of various layers. The new unit is lighter, stronger and more rigid than previous models and costs less to manufacture. (Savile)

**Helium Leak Detection Unit.** This unit has been installed to enable pressure case leak testing to  $10^{-9} \text{ cm}^3 \cdot \text{s}^{-1}$ .

**Automatic Cycling Pressure Test Vessel.** This vessel has been installed to allow the unattended cycling of the 100 psi pressure vessel. The vessel is controlled by a microprocessor based pumping system which monitors both the hydrostatic pressure and the temperature of the fluid medium.

**Computer Assisted Design and Drafting System.** This system has been installed for the design and drafting of mechanical and electronic drawings and circuit board layouts. The system is based on the IBM-PC Computer Group, using both AUTOCAD and DASH-2 software.

**Metal-Photo System.** This system has been installed to provide for in-house manufacturing of photographic text deposited on aluminum plate, primarily for instrumentation front panel assemblies.

**Snowmelt Sectioning Sampler.** To study the effects of the short-term changes in the melting snow water chemistry at the Turkey Lakes site, a new sectioning sampler was designed and manufactured. It is a completely automated battery-powered 24-bottle sampler. The apparatus design was based on that of a commercial water sampler, incorporating a low power microcomputer. In 1984/85, the apparatus successfully collected over 20 samples. (Dolanjski, Savile)

**Computer-Controlled AC Outlets.** With the increased use of the personal computers in the laboratories of the Institute, there is a frequent need to control devices like pumps, solenoid valves, etc., with the computer. Since at the time the appropriate interfacing device was not available on the market, a unit was designed and built here. At present, the unit can control four outlets, with eight planned for the future. (Dolanjski)

## DRAFTING SERVICES SECTION

This Section provides drafting and illustrating support for graphics and visual presentations, technical and scientific illustrations as well as cartographic, mechanical and electronic drawings of a quality suitable for publications.

This Section also provides a photographic service, which includes photography of engineering and scientific research equipment, overhead projection material and slides for conferences and seminars. Outside sources are used for type composing, printing, reprographic and photo-finishing services.

The Section maintains files of all original drawings, illustrations, and negatives of all photographs and reprographics. This service is provided for the divisions of the Institute and for all other directorates, branches and services within Canada Centre for Inland Waters.

## OFFICE SERVICES SECTION

This Section provides office services, word processing, clerical and record-keeping support to all Sections of the Division operations. Office Services also manages the orderly production and distribution of reports and publications on scientific and engineering subjects, implementing the bilingual publishing policy of the Department of the Environment. This Section responds to requests for reprints or copies of unpublished manuscripts, and statistics are kept.

## STAFF LIST

**Chief — T.M. Dick, B.Sc., M.Sc., Ph.D., P.Eng.**

**Secretary — A. Mueller**

**A/Administrative Officer — S. Hicks  
(assigned to Hydraulics Division by  
Staff Services Division, NWRI)**

### Drafting Services Section

#### Head

W.D. Finn

#### Draftspersons

M. Donnelly  
P. McColl  
J. Van Nynatten

### Engineering Services Section

#### Head

F.E. Roy, B.Sc., M.E., mechanical systems  
M.Eng., P.Eng.

#### Project Engineers

R. Desrosiers, B.A.Sc., electro/optical  
M.A.Sc.  
J.S. Ford, B.A.Sc., P. Eng. data systems  
N. Madsen, B.A.Sc., machine designs  
P. Eng.  
J. Valdmanis, B.Eng., sensor systems  
M.A.Sc., P. Eng.

## Environmental Hydraulics Section

### Head

Y.L. Lau, B.A.Sc., river dynamics  
M.A.Sc., Ph.D., P.Eng.

### Researchers

S. Beltaos, B.S., M.Sc., river ice studies  
Ph.D., P.Eng.  
P. Engel, B.Sc., M.Sc. river engineering  
B.G. Krishnappan, B.E., river dynamics  
M.Sc., Ph.D., P.Eng.  
J. Marsalek, Dipl.Eng., urban hydrology  
Can.Tech.Sci., P.Eng.  
H. Ng, B.Sc., M.Sc., urban hydrology  
P.Eng.  
G. Tsang, B.E., ice studies  
M.Eng.Sc.,  
Ph.D., P.Eng.  
J. Wong, B.Eng. river ice studies  
(presently  
on educational  
leave)

## Manufacturing and Technical Development Section

### Head

S.D. Baird

### Electronics Unit

J. Dolanjski  
M. Pedrosa

### Mechanical Unit

R. Boucher (now with National Defence, Ottawa)  
H. Savile

### Calibration and Maintenance Unit

W.J. Cooper  
L. Peer

### Machine Shop

J.G. Ford  
K.K. Kalter  
G. Olsen  
D. Whyte

### Office Services Section

#### Head

M. Hawkins

D. Bowman, Clerk  
N. Snelling, Word Processing Operator

### Shore Processes Section

#### Head

M.G. Skafel, B.A., B.E., coastal engineering  
M.Sc., Ph.D., P.Eng.

### Researchers

C.T. Bishop, B.Sc., M.Sc., coastal engineering  
P.Eng.  
J.P. Coakley, B.Sc., M.Sc., coastal sedimentology  
Ph.D., P.Eng.  
M.A. Donelan, B.Eng., air-water interaction  
Ph.D.



N.A. Rukavina, B.A., coastal sedimentology  
M.Sc., Ph.D., P.Eng.

A.J. Zeman, B.Sc., M.Sc. geotechnical studies

## **Technical Services Section**

### **Head**

**C. DeZeeuw**

## **Geotechnical/Sedimentology Laboratory Services**

K. Salisbury

J. Dalton

## **Laboratory Operations**

R. Klainka

E. Nash (retired September 1984)

G. Voros

## **Scientific Support Unit**

D. Beesley

J. Dalton

G.A. Duncan

W. Moody

T. Nudds

D. Doede

F. Dunnett

J. Heidt

R. Stephens

B. Trapp

## **National Calibration Service**

C. Bil

D. Fekyt

B. Near

M.A. Donelan

American Meteorological Society's Committee on  
"Interaction of the Sea and Atmosphere" —  
Chairman

Canadian National Committee for the Scientific  
Committee on Oceanic Research

J.S. Ford

Mohawk College Technology Advisory Committee

Scientific Equipment Development Group  
(SEDWG)

B.G. Krishnappan

Bridge Hydraulics Project Committee of Roads  
and Transportation Association

CSCE Task Force on Mixing Processes in Rivers

Ph.D. Supervisory Committee, Department of  
Mechanical Engineering, University of Waterloo

Water Quality and Quantity Technical Committee  
Flathead River International Study Board,  
International Joint Commission

Y.L. Lau

Canadian Society for Civil Engineering

Hydrotechnical Division Research Committee

J. Marsalek

Working Group on Urban Hydrology (under the  
International Hydrological Program of UNESCO)

Urban Water Resources Research Council of  
ASCE

Technical Committee for the Waterford River Basin  
Study

Ph.D. Supervisory Committee, Department of Civil  
Engineering, McMaster University

Organizing Committee, 1985 NATO Workshop on  
Urban Runoff

N.A. Rukavina

Ph.D. Supervisory Committee, Department of  
Geography, McMaster University

Program Committee, ACROSES Symposium on  
Cohesive Shores

G. Tsang

IJC Niagara International Board of Control, Ice  
Panel

Canada-U.S. International Ice Information Work  
Group

J. Valdmánis

Current Meter Measurement Committee (affiliated  
with IEEE and MTS)

A.J. Zeman

NRC Subcommittee on Marine Geotechnical  
Engineering

Organization Committee ACROSES Symposium  
on Cohesive Shores — Chairman

## **COMMITTEE MEMBERSHIP**

S. Beltaos

IAHR Working Group on Thermal Regimes

IAHR Working Group on Ice Jams

NRCC Subcommittee on Snow and Ice

NRCC Subcommittee on Hydraulics of  
Ice-Covered Rivers

NRCC Working Group on River Ice Jams —  
Chairman

New Brunswick Subcommittee on River Ice

J.P. Coakley

IUGS Working Group on Modern Methods of  
Grain Size Analysis

IGCP Project 200 (Sea-Level Correlations and  
Applications)

Program Committee ACROSES Symposium on  
Cohesive Shores

T.M. Dick

International Association for Hydraulics Research  
(IAHR) — Council Member 1985/87

Editorial Board, *WHO Water Quality Bulletin*

Associate Committee for Research on Shoreline  
Erosion and Sedimentation (ACROSES) — NRC  
— Chairman



## PUBLICATIONS

- Barnett, P.J., J.P. Coakley, J. Terasmae, and C.E. Winn. 1985. Chronology and significance of a Holocene sedimentary profile from Clear Creek, Lake Erie shoreline, Ontario. *Can. J. Earth Sci.*, 22(8): 1133-1138.
- Beaulieu, G.T., M.G. Skafel, and W.F. Baird. 1984. Offshore breakwater, Wheatley, Ontario. Proc. 19th Coastal Engineering Conference, ASCE, pp. 1929-1939.
- Beltaos, S. 1984. Study of river ice breakup using hydrometric station records. Proc. 3rd Workshop on Hydraulics of River Ice, Fredericton, N.B., pp. 41-59.
- Beltaos, S. 1984. River ice breakup. Submitted to the Proc. of the IAHR Int. Ice Symp., Hamburg, West Germany.
- Beltaos, S. 1984. A conceptual model of river ice breakup. *Can. J. Civil Eng.*, 11(3): 516-529.
- Beltaos, S. 1984. Discussion: Ice jams in shallow rivers with floodplain flow. *Can. J. Civil Eng.*, 11(2): 370-371.
- Beltaos, S. 1984. Closure: River ice jams: Theory, case studies and applications. ASCE.
- Beltaos, S. 1984. Lecture notes on ice jams. Short course on river ice engineering, Fredericton, N.B.
- Beltaos, S. 1984. Discussion: Analysis of breakup and ice jams in the Athabasca River at Fort McMurray, Alberta. *Can. J. Civil Eng.*
- Beltaos, S. 1985. Ice freeze-up and breakup in the Lower Thames River: 1981-82 observations. NWRI Contribution No. 85-05.
- Beltaos, S. 1985. Research on river ice jams and floods: Relevance of hydro-metric measurements and need for additional data. Submitted for inclusion in the Proc. of Winter Discharge Measurement Techniques and Instrumentation Working Group, Peace River, Alberta.
- Beltaos, S. 1985. Ice freeze-up and breakup in the lower Thames River 1982-83 observations. NWRI Contribution No. 85-10.
- Beltaos, S. 1985. Discussion: Comparison of field data with theories of ice progressing in large rivers. *Can. J. Civil Eng.*
- Beltaos, S., and J. Wong. 1984. Downstream transition of river ice jams. NWRI Contribution No. 84-40, to be submitted to ASCE.
- Bishop, C.T. 1984. Floating breakwater feasibility at Confederation Basin, Kingston, Ontario. Hydraulics Division Tech. Note 84-13, prepared for Small Craft Harbours, OR, DFO.
- Bishop, C.T. 1984. Wave hindcast for the sinking of the Stanley Clipper, Long Point Bay, Lake Erie. Hydraulics Division Tech. Note 84-16.
- Bishop, C.T. 1984. Lake Ontario wave hindcast for EPIRB experiments. Hydraulics Division Tech. Note 84-19, prepared for Canadian Coast Guard.
- Bishop, C.T. 1984. Plans and specifications for a floating tire breakwater at Morch Marine, Belleville, Ontario. Hydraulics Division Tech. Note 84-23, prepared for Small Craft Harbours, OR, DFO.
- Bishop, C.T. 1985. Field assessment of floating tire breakwater. Proc. Floating Tire Breakwater Workshop, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi.
- Bishop, C.T., and M.A. Donelan. 1985. Waves and wave forecasting. Submitted to the forthcoming Handbook of Engineering, ASCE, Technomic Publishing.
- Bishop, C.T., J.T. Judge, and M.G. Skafel. 1985. Modelling wave overtopping of a Caisson Island. Proc. Canadian Coastal Conference 1985, NRCC.
- Coakley, J.P. 1984. Comments on survey procedures for monitoring of bottom sediment changes in the vicinity of the Darlington Nuclear Generating Station, Lake Ontario. Hydraulics Division Tech. Note 84-14, prepared for Ontario Hydro.
- Coakley, J.P. 1984. Late Quaternary depositional environments in eastern Lake Erie. 27th Great Lakes Conference, Brock University.
- Coakley, J.P. 1985. Evolution of Lake Erie based on the postglacial sedimentary record below the Long Point, Point Pelee and Pointe-aux-Pins forelands. Unpub. Ph.D. Thesis, University of Waterloo, 361 pp.
- Coakley, J.P., and C.F.M. Lewis. 1985. Postglacial lake levels in the Erie Basin. *Geol. Assoc. of Canada, Pap. 30*, pp. 195-212.
- Cooper, J. 1984. Evaluation report of Guildline model 9450 digital thermometer SN 51888. Hydraulics Division Tech. Note 84-30.
- Desrosiers, R.J. 1984. Electro-optical performance review of a flume profiler fiber optic probe. Hydraulics Division Tech. Note 84-02.
- Desrosiers, R.J. 1984. Water test method for transmittance sensors at NWRI. Hydraulics Division Tech. Note 84-12.
- Desrosiers, R.J. 1984. Brief investigation of sensors used to measure suspended sediment. Hydraulics Division Tech. Note 84-15.
- Desrosiers, R.J. 1985. Flow cytometry — a review of the technique with application to phytoplankton and bacteria. NWRI Contribution No. 85-17.
- Desrosiers, R.J. 1985. Cytometer bibliography. NWRI Contribution No. 85-18.
- DeZeeuw, C.N. 1985. General instructions for visitors working in the Hydraulics Laboratory/Instructions générales à l'intention des visiteurs qui viennent travailler au laboratoire de l'hydraulique.
- Dick, T.M. 1984. Guidelines for the administration of the cost recovery policy in the Hydraulics Division, NWRI/Lignes directrices en vue de l'application de la politique de recouvrement des coûts à la Division de l'hydraulique, INRE.
- Dick, T.M. 1984. Comments on science policy. Hydraulics Division Tech. Note 84-05.
- Dick, T.M. 1985. Rivers, research and sediment. NWRI Contribution No. 85-07.
- Dick, T.M., and J. Marsalek. 1985. Manhole head losses in drainage hydraulics. Presented at the 21st Congress of the IAHR, Melbourne, Australia.
- Dolanjski, J. 1984. Operating instructions for the Biotech rain sampler.
- Dolanjski, J. 1984. Handbook notes for the delay timer.
- Dolanjski, J. 1984. Handbook notes for computer control AC outlets.
- Dolanjski, J. 1984. Handbook notes for the data logger interrogator.
- Donelan, M.A. 1985. Frequency and wave number spectra of wind-generated waves. Scripps Inst. Oceanogr. Advanced Lectures, December 1983, Springer-Verlag.
- Donelan, M.A. 1985. Mixing length model for gas transfer at the air-water interface. Scripps Inst. Oceanogr. Advanced Lectures, December 1983, Springer-Verlag.
- Donelan, M.A. 1985. Attenuation of laboratory "swell" in an adverse wind. Scripps Inst. Oceanogr. Advanced Lectures, December 1983, Springer-Verlag.
- Donelan, M.A., and W.J. Pierson. 1984. Bragg scattering and equilibrium ranges in wind-generated gravity waves — with application to scatterometry. Submitted to *J. Geophys. Res. Oceans*.
- Donelan, M.A., R. Golus, and H.A. Panofsky. 1984. Comparison of bulk and direct methods for estimating fluxes and structure function constants over water. Submitted to *J. Boundary Layer Meteorol.*
- Donelan, M.A., J. Hamilton, and W.H. Hui. 1985. Directional spectra of wind-generated waves. *Phil. Trans. R. Soc. London A315*, pp. 509-562.
- Donelan, M.A., and W.J. Pierson, Jr. 1984. Does the scatterometer see wind speed or friction velocity? Paper in the preprint volume of the International Union of Radio Science Meeting: Frontiers of Remote Sensing of the Oceans and Troposphere from Air and Space Platforms, published in *Proc. NASA Conference Pub. No. 2303*.
- Duncan, G.A. 1984. Particle Size Data Reports. Hydraulics Division Tech. Notes 84-20, 21, 22, 24, 25, 26.
- Engel, P. 1984. Discussion: Bed shear from velocity profiles: A new approach. Submitted to *J. Hydraul. Eng.*, ASCE.
- Engel, P. 1985. Discussion: New approach to calibrating bedload samplers. Submitted to ASCE.
- Engel, P., and C.N. DeZeeuw. 1984. The effect of Columbus type sounding weights on the performance of the Price current meter. NWRI Contribution No. 84-30.
- Engel, P., and C.N. DeZeeuw. 1984. On the effect of changes in geometry and submerged weight of the Price meter rotor. NWRI Contribution No. 84-24.
- Engel, P., and B.G. Krishnappan. 1984. Discussion: Flow resistance in large test channels. Accepted by *J. Hydraul. Eng.*, ASCE.
- Ford, J.S. 1984. Maximum speed for profiling. Hydraulics Division Tech. Note 84-11.
- Ford, J.S. January 1984. The demonstration of a correction technique to improve spatial information for oxygen profiles. NWRI unpub. rep.
- Ford, J.S. 1984. An engineering proposal for a sonde to measure ice jam thickness. Hydraulics Division Tech. Note 84-09.
- Ford, J.S. 1984. Prototype designs for surveys and measurements in an aquatic environment, 1982. NWRI Contribution No. 84-25/Prototypes d'appareils pour les études et mesures en milieu aquatique, 1982. Collection INRE 84-25.
- Ford, J.S. 1984. Prototype designs for surveys and measurements in an aquatic environment, 1983. NWRI Contribution No. 85-01/Prototypes d'appareils pour les études et mesures en milieu aquatique, 1983. Collection INRE 85-01.
- Ford, J.S. 1985. Operating procedures for solid state temperature logger MKI.
- Ford, J.S. 1985. End point determination for a chemical titration using a micro computer. Hydraulics Division Tech. Note 85-04.
- Ford, J.S. 1985. Progress report on the frazil ice recorder.

- Ford, J.S.**, and M.A. Charlton. 1984. Microcomputer system for dissolved oxygen profiles. Submitted to the J. Atmosph. Ocean Technol.
- Ford, J.S.**, and **J. Dolanjski**. 1984. A sonde for profiling having AC power and bidirectional microprocessor communication on a single circuit. Submitted to IEEE J. Oceanic Eng.
- Ford, J.S.**, **M. Pedrosa**, and **J. Dolanjski**. 1984. A solid state logger for temperature. NWRI Contribution No. 85-19.
- Heidt, J.** 1984. Calibration of Thermarine recorders. Hydraulics Division Tech. Note 84-04.
- Heidt, J.** 1984. Method of measuring the towing tank rails. NWRI unpub. rep.
- Heidt, J.** 1986. Pressure discharge curves for a Jacuzzi and a hydrometric pump. Hydraulics Division Tech. Note 86-02, prepared for Sediment Survey Section, WRB.
- Iizuka, I., A. Freundorfer, W. Haras, **G. Tsang**, and D. Wilson. 1984. Measurement of saline ice thickness using a step frequency radar. Submitted to the J. Geophys.
- Judge, J.T. 1983. Annotated bibliography on wave action at and around caisson retained artificial islands. NWRI unpub. Contract Rep.
- Judge, J.T. 1983. Wave action and overtopping spray for caisson retained artificial islands. NWRI unpub. Contract Rep.
- Judge, J.T. 1983. Annotated bibliography on overtopping spray for caisson retained artificial islands. NWRI unpub. Contract Rep.
- Judge, J.T. 1984. Caisson retained islands overtopping and spray. NWRI unpub. Contract Rep.
- Judge, J.T. 1984. Wave action around caisson retained artificial islands. NWRI unpub. Contract Rep.
- Krishnappan, B.G.** 1983. Dispersion of dredged spoil when dumped as a slug in deep water: the Krishnappan model. Proc. Workshop on Drilling Fluid Dispersion Models, Vol. 2, pp. 128–155.
- Krishnappan, B.G.** 1984. Stability of drainage ditch at Madawaska Mines tailing pond. Hydraulics Division Tech. Note 84-18, prepared for Federal Programs Division, EPS, OR.
- Krishnappan, B.G.** 1984. MOBED vs HEC-6: A comparative study. NWRI Contribution No. 84-19.
- Krishnappan, B.G.** 1985. Modelling of unsteady flows in alluvial streams. J. Hydraul. Eng., ASCE, 111(2): 257–266.
- Krishnappan, B.G.** 1985. Comparison of MOBED and HEC-6 river flow models. Can. J. Civil Eng., 12(3): 464–471.
- Krishnappan, B.G.** 1985. Laboratory verification on a mobile boundary unsteady flow model (MOBED). Paper submitted to the J. Hydraul. Res., IAHR.
- Krishnappan, B.G.** 1985. Prediction of sediment sorting using MOBED: Users manual update II. NWRI Contribution No. 85-22.
- Krishnappan, B.G.** 1985. Application of MOBED to Qu'Appelle River between Cravan and Pasqua Lake. NWRI Contribution No. 85-20.
- Krishnappan, B.G.**, and **Y.L. Lau**. 1985. RIVMIX MK-II users manual. NWRI unpub. Rep.
- Krishnappan, B.G.**, and **Y.L. Lau**. 1985. Turbulent modelling of floodplain flows. Paper submitted to the J. Hydraul. Eng., ASCE.
- Lau, Y.L.** 1985. Mixing coefficient for ice-covered and free-surface flows. Can. J. Civil Eng., 12(3): 521–526.
- Lau, Y.L.** 1985. Discussion: Low temperature effects on flow in sand-bed streams. Accepted for publication in the J. Hydraul. Eng., ASCE.
- Lau, Y.L.** 1985. Discussion on the determination of ripple geometry. Submitted to ASCE.
- Lau, Y.L.**, and **B.G. Krishnappan**. 1984. River mixing — state-of-the-art report. Task Group on Mixing Processes in Rivers. CSCE Hydrotechnical Division Research Comm. CJCCE, Vol. 11, pp. 585–609.
- Lau, Y.L.**, and **B.G. Krishnappan**. 1985. Sediment transport under ice cover. J. Hydraul. Eng., ASCE, Vol. III, No. 6, pp. 934–950.
- Lau, Y.L.**, and **B.G. Krishnappan**. 1985. Discussion: Transverse mixing in open channel flow. Accepted for publication in the J. Hydraul. Eng., ASCE.
- Marsalek, J.** 1984. Hydraulic tests of the Canon ductile iron grate. Hydraulics Division Tech. Note 84-10 prepared for Canon Inc.
- Marsalek, J.** 1984. Caractérisation du ruissellement de surface issu d'une zone urbaine commerciale. Sciences et Techniques de l'Eau, 17(2): 163–167.
- Marsalek, J.** 1984. Urban Runoff Peak Frequency Curves. Nord. Hydrol., 15: 85–102.
- Marsalek, J.** 1984. Temporal distribution of design storm rainfall. J. Water Sci. Technol., ASCE, 16: 167–175.
- Marsalek, J.** 1984. Head losses at sewer junction manholes. J. Hydraul. Eng., ASCE, 110(8): 1150–1154.
- Marsalek, J.** 1984. Laboratory investigations of road drainage structures. NWRI Contribution No. 84-35, prepared for the Ministry of Transportation and Communications.
- Marsalek, J.** 1985. Head losses at selected sewer junction manholes. NWRI Contribution No. 85-15.
- Marsalek, J.** 1985. Toxic contaminants in urban runoff: A case study. To be published in the Proc. of the NATO Workshop on Urban Runoff Pollution.
- Marsalek, J.**, and G. Patry. 1984. Urban design floods. A report to the Editors of the Canadian Flood Guide.
- Marsalek, J.**, and H.O. Schroeter. 1984. Loadings of selected toxic substances in the Canadian Great Lakes Basin. Prepared under the Great Lakes Water Quality Program.
- Marsalek, J.**, and W.E. Watt. 1984. Design storms for urban drainage design. Can. J. Civil Eng., 11(3): 574–584. 1984.
- Marsalek, J.**, U. Panu, and **H.Y.F. Ng**. 1985. Investigations of urban runoff in St. John's Newfoundland. A report to the Technical Committee for the Waterford River Basin Study.
- Miles, K., and **N.A. Rukavina**. 1984. System user's manual for nearshore data file. NWRI unpub. rep.
- Mudroch, A., **A.J. Zeman**, and L.L. Kalas. 1982. Calcium carbonate in postglacial Lake Erie Sediment. J. Great Lakes Res., 8(4): 711–718.
- Ng, H.Y.F.** 1984. Energy losses at junction manholes with a lateral. NWRI Contribution No. 85-14.
- Ng, H.Y.F.** 1985. Direct contribution of rainwater to loading of urban storm runoff. NWRI Contribution No. 85-11.
- Ng, H.Y.F.**, and **J. Marsalek**. 1984. Effects of rainwater composition on urban runoff quality. Canadian Hydrology Symp., Laval University, Quebec.
- Pedrosa, M.** 1984. Handbook notes for frazil instrument.
- Pedrosa, M.** 1985. Groundwater microflowmeter. NWRI unpub. rep. (limited distribution).
- Peer, L.** 1985. Quality assurance program manual for MANTEC calibration unit (limited distribution).
- Pierson, Jr, W.J., W.B. Sylvester, and **M.A. Donelan**. 1985. Aspects of the determination of winds by means of scatterometry and of the utilization of vector wind data for meteorological forecasts. J. Geophys. Res. Oceans.
- Pinchin, B.M., C.A. Fleming, **M.G. Skafel**, and D. Aubrey. 1985. Comparison of measured with computed offshore to onshore transformations of directional wave spectra at Pointe-Sapin, N.B. Canadian Coastal Sediment Study. Proc. Canadian Coastal Conference, 1985, NRCC.
- Roy, F.E.** 1984. Program for industry-laboratory projects (PILP) activities at NWRI. NWRI Contribution No. 84-51.
- Roy, F.E.** 1985. Computer aided engineering/computer aided design. NWRI Contribution No. 85-06.
- Roy, F.E.**, and **H.A. Savile**. 1985. Handbook notes for under-ice drifter buoy.
- Rukavina, N.A.** 1985. Manual on the field use of a portable computer terminal. NWRI unpub. rep.
- Rukavina, N.A.** 1985. Operations guide Lac St-Louis bottom sediment survey. Hydraulics Division Tech. Note 85-05, prepared for IWD, QR.
- Rukavina, N.A.** 1985. Operations guide — St. Clair River Sounding Survey. Hydraulics Division Tech. Note 85-09, prepared for UGLCC.
- Rukavina, N.A.** 1985. Preliminary results — thickness measurements of Lake St. Clair sediments by echo sounding. Hydraulics Division Tech. Note 85-08, prepared for APSD, NWRI.
- Rukavina, N.A.** 1986. Lac St-Louis bottom types — CHS labels. Hydraulics Division Tech. Note 86-01, prepared for Can. Hydrographic Service, QR.
- Rukavina, N.A.**, and **A.J. Zeman**. 1985. Erosion and sedimentation along a cohesive shoreline — the north-central shore of Lake Erie. Submitted to the J. Great Lakes Res.
- Salisbury, K.** 1984–85. Particle size data reports. Hydraulics Division Tech. Notes 84-27, 28, 85-02, 03 A to K.
- Schwab, D.J., J.R. Bennett, P.C. Liu, and **M.A. Donelan**. 1984. Application of a simple numerical wave prediction model to Lake Erie. GLERL Contribution No. 382, J. Geophys. Res., Vol. 89, C3, pp. 3586–3592.
- Skafel, M.G.** 1984. Offshore wind and wave data, 1983, Pointe-Sapin, New Brunswick, CCIW wave direction buoy. Submitted to the Canadian Coastal Study.



- Skafel, M.G.** 1984. Shore protection for the North Berm, CCIW. Hydraulics Division Tech. Note 84-29.
- Skafel, M.G.** 1985. Offshore wind and wave data, 1984, Stanhope Beach, P.E.I. CCIW wave direction buoy. NWRI Contribution No. 85-03.
- Skafel, M.G.** 1985. Wave forces on submarine pipelines: A review. Report funded in part by the Panel on Energy Research and Development (PERD), Marine Engineering Committee, Project No. 6.2.3.07. NWRI Contribution No. 85-135.
- Skafel, M.G.** 1985. Shoreline evolution models annotated bibliography. NWRI Contribution No. 85-137.
- Skafel, M.G., and C.T. Bishop.** 1984. Entrance configuration, Grand Bend, Ontario. Hydraulics Division Tech. Note 84-08, prepared for Small Craft Harbours, OR, DFO.
- Skafel, M.G., and B.G. Krishnappan.** 1984. Suspended sediment distribution in wave field. ASCE J. Waterw. Port Coastal Ocean Eng., 110(2): 215-230.
- Skafel, M.G., C.T. Bishop, and J.P. Coakley.** 1985. Shore protection alternatives for the Marentette drainage scheme. Hydraulics Division Tech. Note 85-06, prepared for Agriculture Canada and Parks Canada, DOE.
- Skafel, M.G., J.T. Judge, and C.T. Bishop.** 1984. Wave field around caisson retained artificial islands. Proc. Canadian Coastal Conference 1985, NRCC.
- Tsang, G.** 1984. An instrument for measuring frazil concentration. J. Cold Regions Sci. Technol., 10: 235-249.
- Tsang, G.** 1984. Modelling criteria for bubble plumes — a theoretical approach. Can. J. Civil Eng., 11: 293-298.
- Tsang, G.** 1984. Concentration of frazil in flowing water as measured in the laboratory and in the field. Proc. IAHR Ice Symp.
- Tsang, G.** 1985. Frazil measured in the laboratory and in the field. Submitted to the J. Nord. Hydrol.
- Tsang, G.** 1985. Lachine Rapids ice study — measurement and analysis. Preliminary report prepared for Hydro-Québec.
- Tsang, G., and T. Hanley.** 1985. Frazil formation in water of different salinities and supercoolings. J. Glaciol. 31(108): 74-85.
- Valdmanis, J.** 1985. A feasibility proposal for measuring the efficiency of the Annapolis Power Station. Hydraulics Division Tech. Note 85-01, prepared for Energy Development Section, WP&M, Ottawa.
- Wong, J., and S. Beltaos.** 1985. Preliminary study of grounded ice accumulation. NWRI Contribution No. 85-09.
- Wong, J., S. Beltaos, and B.G. Krishnappan.** 1984. Seepage flow through simulated grounded ice jam. Submitted to the Can. J. Civil Eng. for presentation as a Technical Note.
- Wong, J., S. Beltaos, and B.G. Krishnappan.** 1984. Laboratory tests on surges created by ice jam releases. Submitted to the Can. J. Civil Eng. for presentation as a Technical Note.
- Zeman, A.J.** 1984. Laboratory test of sediment erodibility. Part 1. Equipment, theory, and calibration. NWRI Contribution No. 85-04.
- Zeman, A.J.** 1984. Review of Port Granby. Hydraulics Division Tech. Note 84-17, prepared for Federal Programs Division, EPS.



## NWRI PACIFIC AND YUKON REGION

The Pacific and Yukon Branch of the National Water Research Institute is responsible for the Department of the Environment's water management and limnological research in British Columbia and the Yukon Territory. Formed in 1971, the Branch undertakes applied and basic research to determine the ecological sensitivity and response of regional lakes and rivers to nutrient pollution, biocide contamination and construction of large-scale, hydroelectric impoundments and diversions. Traditional limnological knowledge is not easily applied to the solution of the region's water management problems. Unlike Prairie and Shield systems, most British Columbia and Yukon lakes are long, narrow, deep systems strongly influenced by riverine throughflow and hydrographic variability.

Traditionally, the Branch research program has involved a mixture of longer-term interdisciplinary projects examining the general effects of development (e.g., eutrophication, impoundment) on typical lake or lake/river systems, and shorter-term applied projects aimed at development of rehabilitation strategies at specific sites. In 1983, however, the decision was reached to disband the regional branches of NWRI and to relocate staff to an integrated research facility, the National Hydrology Research Centre, in Saskatoon, Saskatchewan, in April 1986. As a result, the current program focus has been to complete and document ongoing projects prior to relocation. These projects include river eutrophication research in central British Columbia, studies of limnology in Yukon River headwater lakes, and rehabilitation strategies for eutrophic southern British Columbia lakes.

### SOUTHERN LAKES

**Thompson River.** The joint research project with Weyerhaeuser Canada Ltd. continued in 1984/85 and 1985/86. The multiple, continuous-flow facility for periphyton studies was constructed next to the South Thompson River at Chase, B.C. Together with a laboratory trailer, the facility enabled year-round experiments on periphyton accumulation rates and physiology. One experiment examined periphyton photosynthesis for changes in both seasonality and response to the growth-limiting nutrient phosphorus. Six additional experiments have been completed in which the growth kinetics of attached algal communities were examined under the influence of differing N:P ratios and P-pulsing regimes. The influence of natural UV-light on periphyton productivity has also been quantified. Results of these experiments are being analyzed in preparation for publication. Short-term colonization dynamics of periphyton algae were examined using fast-flushing continuous-flow light and dark troughs. Significant differences in periphyton biomass, chlorophyll *a* and algal taxonomic composition between the two parallel troughs were noted within 24 hours. Experiments commencing at the onset of nighttime darkness showed that the rates of algal immigration during the night period were similar in both troughs. Within 4.5 hours of sunrise, however, certain diatom species, most notably *Hanneae arcus* (Ehr.) Patr. and *Diatoma tenue* Ag., selectively emigrated from the dark trough while remaining in the light trough. Better adhering species such as *Achnanthes*

*minutissima* required light deprivation for two photo-periods before significant emigration was noted. Results from substratum-inversion experiments and data on the loss rates of neutral red-stained cells suggested that the mechanism(s) for the rapid differential egress of cells from the dark trough involved an active process which may be associated with changes in cell buoyancy on the disruption of natural light:dark cycles.

Another smaller trough facility was built adjacent to the Thompson River at the Weyerhaeuser Canada Ltd. pulp mill site in Kamloops, B.C. This will provide a direct assessment of the effects of kraft mill effluent on periphyton growth rates and physiology. Two preliminary experiments were completed in October 1985, and the spring of 1986, corresponding to the periods of nuisance periphyton accumulations in the river downstream from the mill. (Bothwell, Jasper, Bolin, Suzuki, Daley)

**Wood Lake.** Thermistor chain data from Wood Lake, located in the Okanagan Valley, were analyzed for internal waves. It was discovered that waves of the first and second baroclinic modes dominated the oscillations of the lake's thermal structure. The lake responded to a wind event by initiating a first-mode seiche, which was followed by a second, as the initial wave was damped. Because the period of the second-mode approximates that of diurnal winds, it is thought that a resonance effect is responsible for maintaining the second-mode oscillations although weak currents were observed associated with second-mode motions. (Wiegand)

**Kootenay Lake.** Two years of thermistor chain records obtained in Kootenay Lake were also analyzed for internal waves. Internal seiches dominated the thermal structure of the lake, while internal surges were an extraordinary feature of the data. The periods of the dominant members of the internal wave field were determined mainly by morphometry, but varied seasonally with stratification. The wind, which initiates internal seiching, also modifies stratification. In a large lake like Kootenay, stratification varies not only spatially but also at time scales similar to those of the internal seiche. Hence the shape and frequency of the waves can vary as they pass through the lake. (Wiegand, Carmack)

### NORTHERN LAKES

**Yukon River/Lake Laberge.** The large lakes and rivers of Canada's North have rich histories as exploration and trade routes and have played an important role in economic development. Their importance as a resource has not diminished owing to their potential use for water storage and power generation. Figure 28 shows a hypothetical northern setting illustrating the central role water plays in social and economic development.

A joint study with Water Resources Branch on the seasonal ice cycle in the Yukon River and Lake Laberge was carried out over the winters of 1984-86. Measurements were made of water temperature, ice accumulation and thickness, snow cover, frazil formation and accumulation under the ice, and

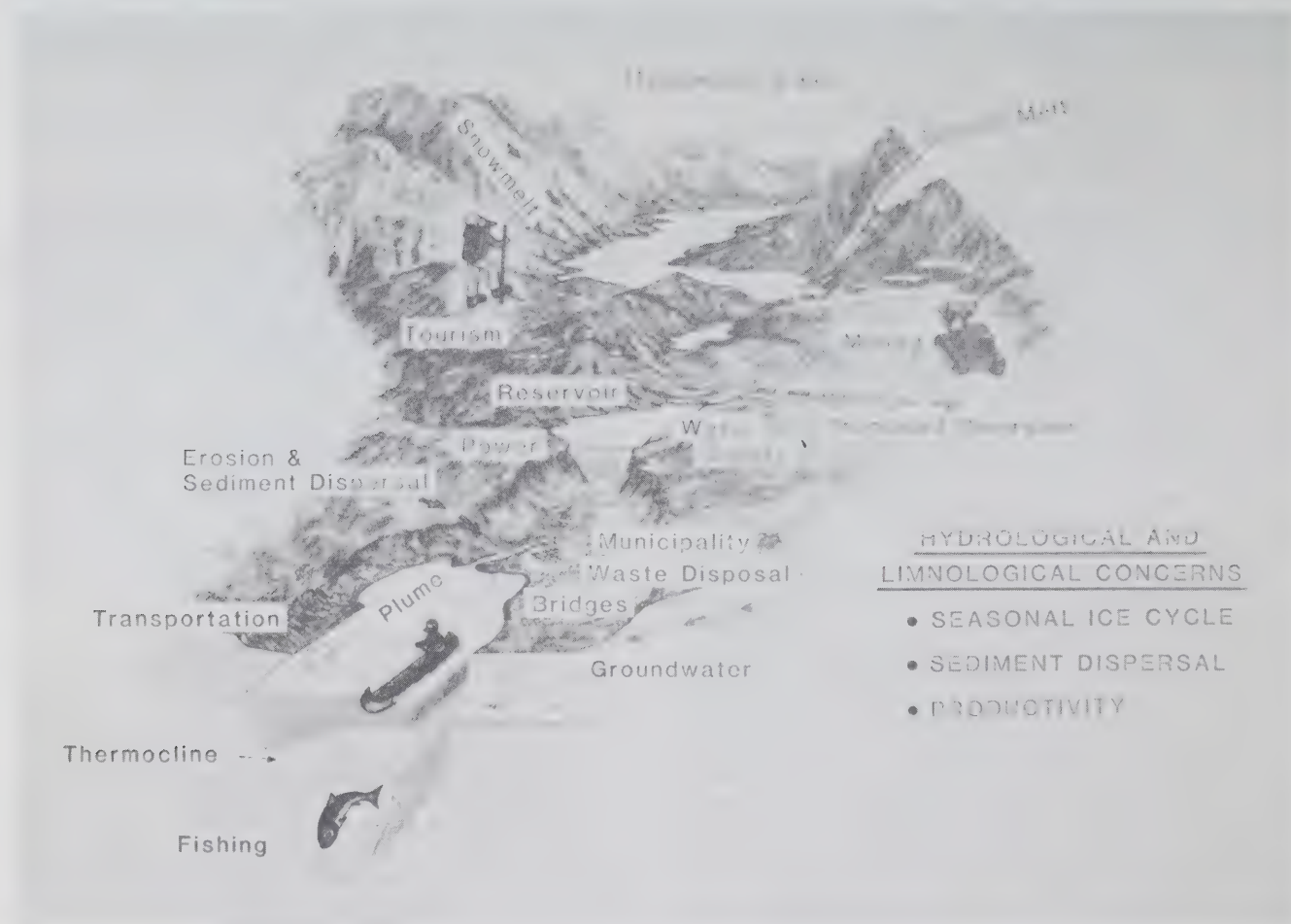


Figure 28. Hydrological and limnological concerns.

degradation of frazil dams. Surveys were also conducted of conductivity/temperature/depth in crosslake and downriver transects. Under-ice moorings recorded temperature and current speed and direction. Detailed through-the-ice measurements of river velocity were also recorded. Several reports on these findings are nearing completion. (Carmack, Alford, Marles, Chamberlain)

Analysis of the data for evidence of internal waves is currently being carried out for Lake Laberge. An attempt is being made to characterize the internal wave field in a statistical sense as well as to describe its seasonal dynamic interaction with river inflow. (Wiegand)

Results from the chemical and biological sampling program on Atlin, Tagish, Marsh and Laberge lakes have been analyzed. Nutrient levels are very low, as are algal and zooplankton biomass, indicating that the lakes are ultra-oligotrophic. Physical factors (temperature, flushing rate, turbidity, and mixing) have pronounced effects on the chemistry and biology of these lakes. With residence times of these lakes varying two orders of magnitude, and the Yukon River being the principal water transfer route (up to 97% of the Marsh Lake input), this suite of lakes is of value to northern reservoir modellers. Marsh Lake is a particularly interesting example of a fast-flushing, shallow northern lake with unusual warming characteristics.

Phosphorus levels are very low ( $DP < 5$  ppb). The major component of total phosphorus was particulate (61% of the growing season total) and is associated with the riverine suspended sediments. Work on the bioavailability of this material is now being conducted. The average growing season total nitrogen was also low (76 ppb), but average nitrate values remained above the detection limit throughout the growing season.

Algal biomass was very low and algal assemblages were dominated by chrysophytes and cryptophytes. Zooplankton biomass was also low, far lower than those reported for smaller Yukon lakes. The growing season mean zooplankton biomass was significantly correlated to total nitrogen but not to total phosphorus, perhaps reflecting nitrogen incorporation into zooplankton protein. (Kirkland, Gray)

## LAKE RESTORATION

**Kootenay Lake.** Many of the important recreational and fisheries lakes in southern British Columbia have undergone nutrient eutrophication, a process often complicated by upstream hydro impoundment activities. One of the most important of these intermontane systems is Kootenay Lake in southeastern British Columbia. A large study in the mid-1970s by



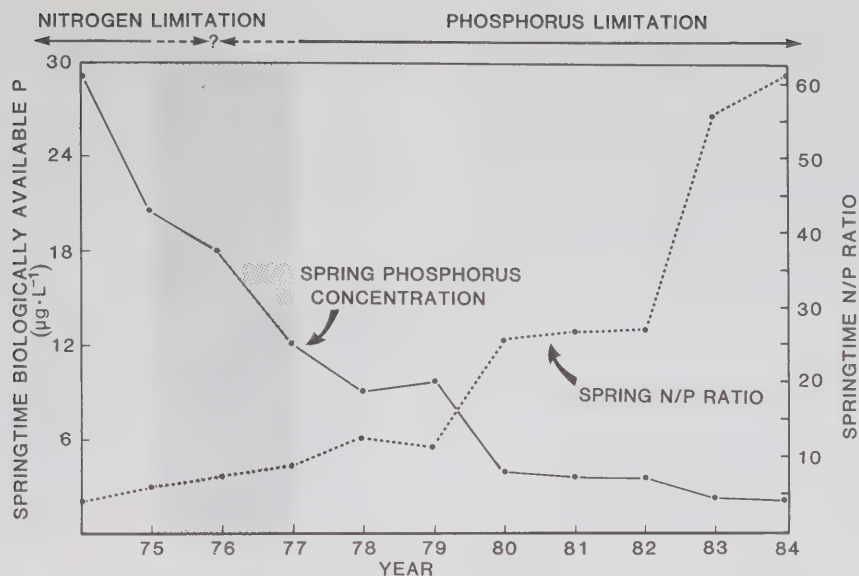


Figure 29. Springtime SRP concentrations and inorganic N/P ratios in Kootenay Lake, B.C., 1974–1984.

this Branch described the effects of phosphorus pollution and its subsequent removal on the lake. The report warned that the combined effects of nutrient removal and upstream impoundments could possibly impoverish the lake to the point that fishery productivity might decline significantly. Recent (1983–85) B.C. Fisheries Branch data now suggest that kokanee and rainbow trout populations may indeed be declining. As a result, an in-depth re-examination of historical data on nutrients, phytoplankton and zooplankton was undertaken in an attempt to link declining nutrients and fish productivity.

Despite a tenfold decline in average water-column phosphorus concentrations over the last 10 years (Fig. 29), average chlorophyll levels have declined by only 20% to 50% (Fig. 30). In addition, the annual average biomass crops of herbivorous zooplankton and of *Mysis relicta*, an introduced invertebrate predator, while variable, also showed no downward trends (Fig. 30). The apparent lack of biological response to phosphorus reductions is explained partly by changes in N:P ratios. At the peak of the P pollution, N:P ratios were below 1, and phytoplankton biomass was strongly N-controlled. Hence, large decreases in P were required to bring springtime N:P ratios back above 10, where P control could be re-exerted. This did not occur until early 1980. Second, there is indirect evidence that epilimnetic phosphorus recycling efficiency has increased as spring P concentrations have declined, so that growing season productivity remained essentially N-controlled even at higher N:P ratios. Under these conditions, large decreases in zooplankton standing crop would not be expected. Therefore, the decreases in fish stocks if confirmed cannot be directly ascribed to a general decline in lake productivity. Proposals for large-scale, long-term aerial fertilization of the lake were rejected as too risky and cost-ineffective. (Daley, Gray)

**Wood Lake.** The sources of soluble reactive phosphorus (SRP) and dissolved inorganic nitrogen (DIN) to the trophogenic zone of Wood Lake during the growing season were evaluated with a new accounting procedure. The external loading (fluvial, atmospheric, groundwater) and hypolimnetic flux were compared with the starting load during four intervals of the growing season (Fig. 31). The starting load was the

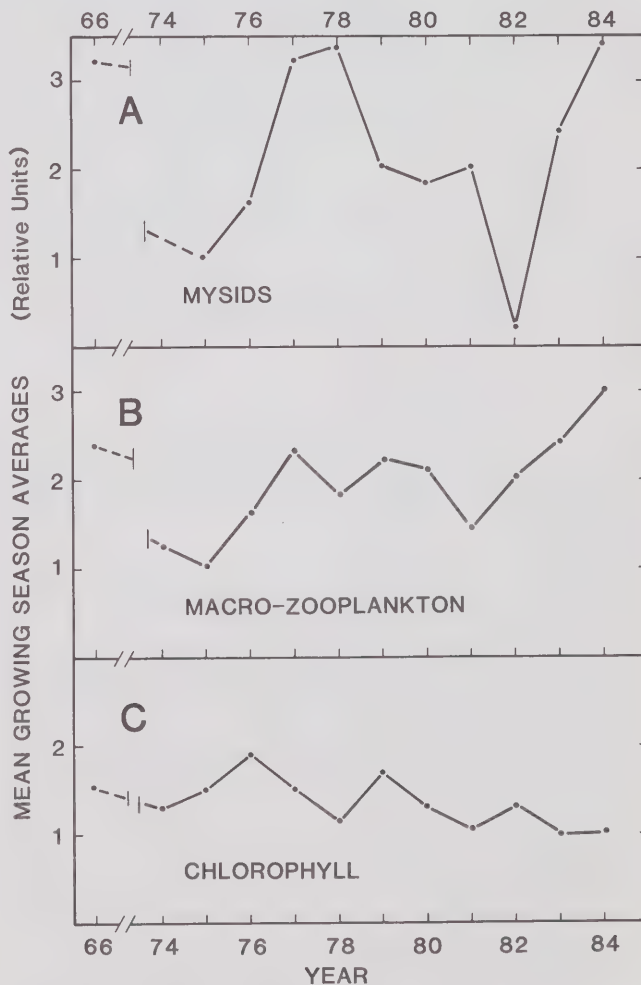


Figure 30. Relative changes in average growing season standing crops of A – mysids, B – macro-zooplankton and C – algal chlorophyll, in Kootenay Lake, B.C., 1966–1984.



content of SRP or DIN in the trophogenic zone at the beginning of each interval. This analysis highlighted the dominance of the starting load in spring and the hypolimnetic flux in late summer and fall. The analysis was useful from a water management viewpoint because it demonstrated that the midsummer blue-green algal bloom was dependent on the starting load of SRP in early summer. This component could be reduced considerably if the spring diatoms were able to take up more SRP and then transport the phosphorus to the hypolimnion. Fertilization of the spring bloom with nitrate was therefore recommended. (Gray, Kirkland)

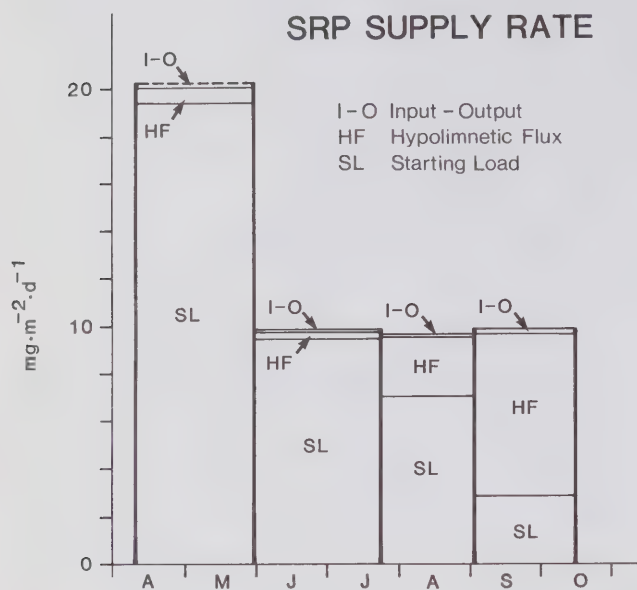


Figure 31. Daily areal supply rate of soluble reactive phosphorus for the trophogenic zone of Wood Lake, B.C.

## ADVICE TO MANAGEMENT

Over the last two years, Branch scientists have provided expert advice and technical information to the following organizations:

- British Columbia Ministry of Environment, Fisheries Branch, on the feasibility of fertilizing Kootenay Lake and on the limnological status of the lake
- British Columbia, Ministry of Environment, Water Management Branch, on loading objectives for six Okanagan Valley lakes using a model developed by Dr. B. Kenny, NWRI, Western and Northern Branch
- British Columbia, Ministry of Environment, Water Management Branch, on evaluating the effectiveness of iron chloride treatment of Wood Lake to decrease phosphate levels
- British Columbia, Ministry of Environment, Waste Management Branch, on a monitoring schedule and parameters for a model to determine the response of Skaha Lake to various sewage treatment options
- Environmental Protection Service on the limnological impact of the Quinsam open-pit coal-mine development on Vancouver Island
- Environmental Protection Service and DIAND on the results of a reconnaissance of the downstream effects of

effluent from the Whitehorse City sewage treatment plant. Tertiary treatment was judged unnecessary at this time.

Staff scientists have also reviewed journal papers and research proposals and acted on student thesis committees.

## STAFF LIST\*

**Branch Chief — Dr. R.J. Daley**  
**Office Manager — Ms. S.E. Roberts**

### Researchers

Dr. M.L. Bothwell	biological limnology
Dr. E.C. Carmack	physical limnology
Dr. C.H. Pharo	geophysical limnology
Mr. C.B.J. Gray	chemical limnology
Mr. S. Jasper	biological limnology
Mr. R.A. Kirkland	chemical limnology
Mr. R.C. Wiegand	physical limnology

### Technical Staff

Ms. V.A. Chamberlain  
 Mr. E.W. Marles  
 Ms. K.E. Suzuki

\* Due to the Branch relocation to Saskatoon, information with respect to the degrees held by staff members was unobtainable at the time of publication.

## COMMITTEE MEMBERSHIP

C.H. Pharo  
 Regional Inland Waters Directorate Health and Safety Committee — Chairman  
 DOE Diving Safety Committee  
 IJC Flathead International Study Board — Secretary

R.C. Wiegand  
 Regional EDP Users Committee

## PUBLICATIONS

- Alford, M., and E.C. Carmack.** 1986. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1983/84. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 152. In press.
- Alford, M., and E.C. Carmack.** 1986. Observations on ice cover and streamflow in the Yukon River near Whitehorse during 1984/85. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 155. In press.
- Alford, M., E. Marles, and E.C. Carmack.** 1985. An open terrain sled for use on ice-covered lakes. IWD Regional Rep., Vancouver, B.C., 8 pp.
- Bothwell, M.L.** 1985. Phosphorus limitation of lotic periphyton growth rates: An intersite comparison using continuous-flow troughs (Thompson River System, B.C.). Limnol. Oceanogr., 30:527-542.
- Carmack, E.C.** 1986. Circulation and mixing in ice-covered waters. In *Air-Sea-Ice Interaction*, N.J. Untersteiner (ed.), NATO Advanced Studies Institute Series, Plenum.
- Carmack, E.C., and M. Alford.** 1985. Factors leading to a mild breakup of the Yukon River near Fort Selkirk. IWD Regional Rep., Vancouver, B.C.
- Carmack, E., and M. Alford.** 1985. Preliminary results of studies on the mid-winter streamflow and ice regime of the Thirty Mile Reach of the Yukon River: Observations in 1985. IWD Regional Rep., Vancouver, B.C.
- Carmack, E.C., R.C. Wiegand, C.B. Gray, R.J. Daley, C.H. Pharo, and S. Jasper.** 1986. Mechanisms influencing the circulation and distribution of water masses in a medium residence-time lake. Limnol. Oceanogr. In press.

**Carmack, E.C., R.C. Wiegand, E.W. Marles, M. Alford, and V.A. Chamberlain.** 1986. Physical Limnology of an Ice-Covered Lake with Through-Flow: Lake Laberge, Yukon Territory. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 157. In press.

**Jasper, S., M.L. Bothwell,** and R. Mitchell. 1984. A multiple trough apparatus for year-round studies of periphyton. IWD Regional Rep., Vancouver, B.C., 16 pp.

**Kirkland, R.A., and C.B. Gray.** 1986. Reconnaissance of the chemical and biological limnology in four large lakes of the Yukon River Basin. Environment

Canada, Inland Waters Directorate, Sci. Ser. No. 153. In press.

**Marles, E.W.** 1985. Limnological survey techniques from small aircraft. Environment Canada, Inland Waters Directorate, Tech. Bull. No. 139, Ottawa, 33 pp.

**Wiegand, R.C., and E.C. Carmack.** 1986. The climatology of internal waves in a deep temperate lake. J. Geophys. Res. In press.

**Wiegand, R.D., and V.A. Chamberlain.** 1986. Internal waves of the second vertical mode in a stratified lake. Limnol. Oceanogr. In press.

The Western and Northern Branch of the National Water Research Institute serves the research needs of the three Prairie provinces and the Northwest Territories. Increasing economic growth and the generally poor quality of water in many prairie communities are causing renewed attention to the historic water supply-demand imbalances in Western Canada. Potential expansion of irrigated and dryland agriculture, increasing demands for water diversion, and the continued development of resource industries and related industrial complexes are raising serious concerns over water supplies and the potential problems of toxic chemicals in western drainage systems. Potential megaprojects in the Mackenzie River Basin are also generating concern for the future of northern drainage systems. These developments are occurring at a time when the federal government is espousing the principles of sustained development without damage to ecological stability.

During the past year research was carried out on the rivers and lakes of the Qu'Appelle Valley (Saskatchewan), Southern Indian Lake and its related reservoirs (northern Manitoba), and the Saskatchewan and Mackenzie River systems. Our activities strike a balance between the practical concerns of toxic substances and the fundamental understanding of nutrient and contaminant behaviour in prairie lakes and rivers. This blend of research achieves the dual objective of appropriate response to regional concerns and the increase of knowledge necessary to meet the long-term objectives of DOE in this region.

### TOXIC CONTAMINANTS

**Mackenzie River Study.** Complaints of fish stock degradation together with increasing mining and hydrocarbon developments in the Mackenzie Basin led to a request for research evaluation of organic and inorganic pathways in the Mackenzie River. A synoptic sampling program was completed during summer discharge conditions in 1985; a high flow sampling program is scheduled for July 1986. The NWT Program Office, NWRI-Winnipeg and the Environmental Contaminants Division of NWRI-CCIW are co-participants. (Ongley)

**Saskatchewan Basin Study: North Saskatchewan River.** The rationale and technology developed for the Tobin Lake Project have been extended to the North Saskatchewan River to study the pathways, fate and ecological impact of contaminants in prairie river systems. The purpose of this study is to develop a rational and cost-effective approach for assessing the impact of toxic substances by (1) determining the presence and significance of toxic substances in water and sediment (suspended and bottom) samples from selected locations in the North Saskatchewan River using nematode and bacterial bioassay techniques and by surveying the responses of benthic communities; (2) evaluating the biogeochemical processes involved in the spatial and temporal degradation of selected organic contaminants as downstream recovery occurs; (3) determining the relative contributions of point and non-point sources of contamination to aquatic sys-

tems and assessing the role of the hydrologic regime in the transport of water- or sediment-bound contaminants; and (4) evaluating the ecological impact of selected organic contaminants or benthic organisms. *In situ* determination of chemical stress by benthic organisms (ecotoxicology) may prove more realistic for environmental impact assessment purposes than bacterial or other standard tests for toxicity which are not realistic surrogates of prairie aquatic systems.

The river was divided into nine approximately equidistant sections reflecting point sources, tributary inputs and existing monitoring sites. Each section was sampled in replicate for water, suspended solids and (when possible) bottom sediments. Sampling was conducted during low flow in August 1983 and again during high flow in June of 1984.

The 1983 summer low flow data for physical, nutrient and metallic variables have been made available in an interim report (Ongley, 1984). An end-of-year report for the Toxic Chemicals Management Program (Ongley *et al.*, 1985) will contain spring 1984 data, plus selected organic chemistry, comparative results of nematode bioassay of water versus suspended sediments, and biological species lists from selected sites.

The program has broad relevance to toxic chemical management, both in terms of environmental sensing procedures and control protocols in river and river-lake systems of Canada. It is anticipated that this study will lead to improved monitoring strategies by federal and provincial agencies. (Ongley)

**The Saskatchewan Basin Study: Tobin Lake.** Tobin Lake is a primary sink for residues from pesticide-derived compounds, industrial waste products and other potentially toxic environmental contaminants from throughout the greater prairie region. Chemical properties of individual pollutants are modified and integrated through physical, chemical and biological processes to the extent that the total effect of a large number of minor pollutants may be as great as, or greater than, that of single major pollutants. The objectives of the Tobin Lake study were (1) to establish the relationship between morphological deformities in Chironomidae (Diptera) larvae and contaminant levels in aquatic environments and (2) to develop a "biological screening tool" to detect the presence of toxicants and assess their cumulative effect in aquatic ecosystems.

The potential for deformities in chironomid larvae is immense and the number of responses to chemical stress is great. Deformities may range from mildly abnormal mouthparts (Fig. 32) to grotesque thickening and fusing of all body structures. To date, the usefulness of these deformities as a tool for monitoring environmental contaminants has been limited by the lack of comparable data from stressed and unstressed populations and the lack of standardized procedures and terminology.

Indices based on the incidence and severity of deformation in the antennae of *Chironomus* larvae show that antennae are very sensitive to low-level, chronic contamination. Antennal deformities (Fig. 33) range from simple reduction in length of individual segments to fusion, deformation or loss of all ancillary structures or segments. In comparatively uncontaminated



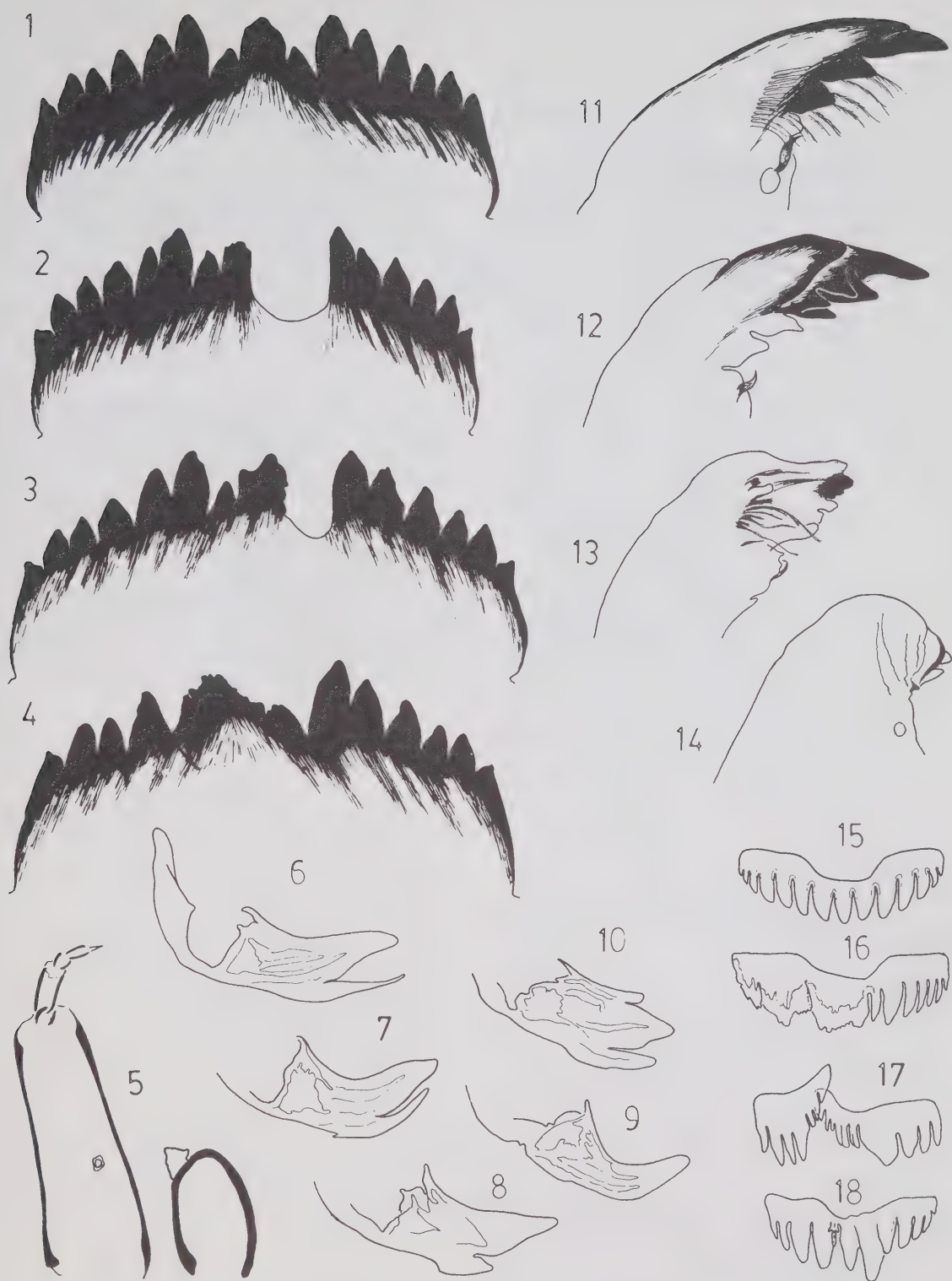


Figure 32. Morphological deformities in the mouthparts of *Chironomus* Meigen: 1 — normal and 2, 3, 4 deformed menta; 5 — normal and deformed antennae; 6 — normal and 7, 8, 9, 10 deformed premandibles; 11 — normal and 12, 13, 14 — deformed mandibles; 15 — normal and 16, 17, 18 deformed epipharyngeal pecten.

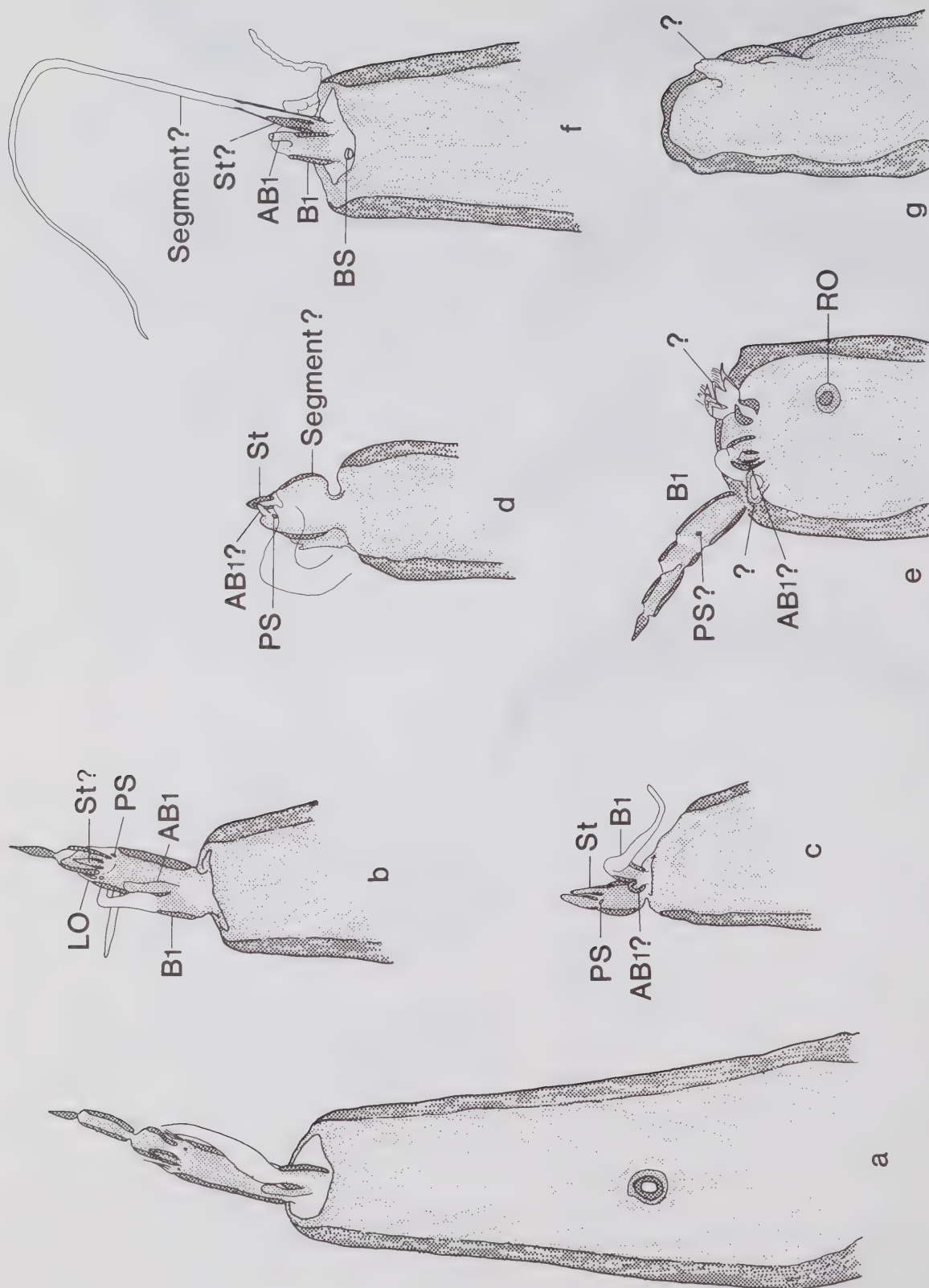


Figure 33. Deformed antennae of *Chironomus* Meigen. (a) Normal antennae. Deformed antennae showing: (b,c) loss of distal segments; (d) questionable second segment; (e) displacement of blade (B1) and accessory blade (AB1), unknown structures and reduced length; (f) fusing of segments and displacement of peg sensillum (PS); (g) fusing of apex of basal segment, loss of ring organ (RO) and unknown structures. Other structures are (LO) organs of Lauterborn, (DP) digitiform processes, (BS) basiconic sensillum. Nomenclature after Warwick (1980). St = style.

areas of Last Mountain Lake, the incidence of deformed antennae was 1.19%; in contrast, the rates were 8.43% and 6.97% in contaminated Tobin Lake. The index of severity of antennal deformation (ISAD) shows the same trends ranging from 0.12 in Last Mountain Lake to 1.64 and 1.19 in Tobin Lake Sites V and VI, respectively. Preliminary experimental data show that both indices decrease as concentration of contaminant increases. These data suggest that the ability of antennae to respond to higher concentrations of contaminants is rapidly saturated and the response is shifted toward the more heavily sclerotized structures of the chironomid head capsule. The inverse relationship between deformed antennae and toxic concentrations indicates the sensitivity of chironomid antennae to low levels of contaminants and suggests increased larval mortality at higher concentrations. Research on the significance of other deformities in the larval head capsule and body is continuing and will eventually be included in an overall biological index for monitoring aquatic contamination. (Warwick)

**The Qu'Appelle River Study.** Concern has been expressed about mercury levels in the Moose Jaw River — Qu'Appelle River-Lake system. The objective of the study was to investigate biogeochemical pathways of mercury and other heavy metals in the river-lake system.

Research revealed that mercury concentrations increased in the river systems below the cities of Moose Jaw and Regina. Microbial methylation of mercury is strongly stimulated by nutrients from sewage effluents and algal blooms — especially at certain times of the year such as autumn when river discharge is greatly reduced (Fig. 34). Methylation apparently is controlled primarily by trophic conditions, rather than by the amount of inorganic mercury from which methyl mercury is

synthesized. During the spring flood, when discharge is high and nutrient levels low, methyl mercury levels were low despite high inorganic mercury levels.

The two-year project is now complete. A paper on this work was presented at the Environmental Contaminants International Conference (London, England) and an abstract published in the conference proceedings. A draft manuscript has been prepared for publication. (Jackson)

**The Southern Indian Lake—Notigi Reservoir Study: Methylation and Demethylation Processes.** Mercury levels in fish from Southern Indian Lake—Notigi Reservoir system rose to undesirable levels as a result of the Churchill-Nelson River Diversion. The purpose of the study was to investigate the effects of environmental changes on the microbial methylation and demethylation of mercury in the sediments from former lake basins flooded by impoundment.

Sediment samples were collected for chemical analysis and use in a laboratory experiment to investigate the effects of different physio-chemical variables on rates of methylation and demethylation of mercury by sedimentary microorganisms. The research has shown that organic nutrients introduced into the aquatic environment from flooded land have accelerated the methylation of inorganic mercury from natural sources.

Experimental results have indicated that the rate of methylation is optimized by addition of organic and carbonate nutrients and by the exclusion of both oxygen and sulphide. Comparison of methylation and demethylation processes under different physio-chemical conditions showed that the rate of demethylation did not vary, in the presence or absence of oxygen, if organic nutrients were added. Clay minerals had little effect on the rate of methyl mercury production but greatly increased the rate at which the methyl mercury was subsequently broken down. Thus, the study suggests that enhanced aeration and clay deposition could favour demethylation at the expense of methylation. Further research is currently being done on effects of clay minerals, oxides, humic matter and various heavy metals on the methylation of mercury by sedimentary microbes.

The project is now complete. A seminar and abstract were presented at a conference and a work-in-progress meeting conducted by the Steering Committee administering the Canada-Manitoba Mercury Agreement; a draft manuscript for publication and a final report for presentation to the Steering Committee are in preparation. The project was supported by Canada Water Act funds granted under the terms of the Canada-Manitoba agreement and the funds from the Toxic Contaminants Management Program. (Jackson)

**The Southern Indian Lake—Notigi Reservoir Study: Bioaccumulation of Mercury.** Mercury levels in commercial fish catches from the Southern Indian Lake—Notigi Reservoir System rose to undesirable levels following impoundment and flooding under the Churchill-Nelson River Diversion scheme. Two mechanisms are identified in the literature as routes for mercury accumulation in fish: (1) absorption across the gill membrane from water and (2) ingestion of mercury-contaminated food. The objective of this study was to examine some of the factors governing the transmission of mercury to fish via the latter route. Particular attention was given to the effects of mineral sediment accumulation from bank erosion on the availability of mercury to the benthic community, its effect on the size and composition of the community that acts as the medium of transmission, and the effects of growth rates on body burdens of mercury in individual members of these communities.

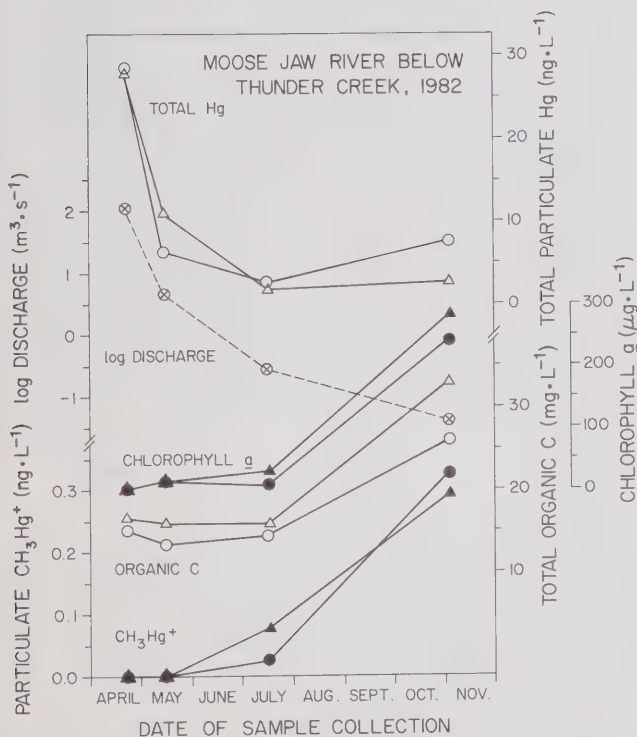


Figure 34. Physical and chemical parameters associated with mercury methylation in the Moose Jaw River at Moose Jaw, Saskatchewan.



Samples of benthic communities and bottom sediments were collected from throughout the Southern Indian Lake–Notigi Reservoir System from sites representing a gradient of different physico-chemical changes and analyzed for mercury content. The results suggest that mineral sediment interference reduces the size of benthic communities and slows their rate of growth by restricting the availability of food resources (probably through burial). Organisms with slower growth rates tend to have higher body burdens of mercury, but because the size of the communities is reduced, less mercury is available for transmission up the food chain. In areas where mineral sediments do not interfere with food availability, body burdens are diluted by rapid growth rates. The reduction in individual body burdens, however, is more than compensated for by the greater populations of benthic organisms inhabiting this more amenable type of environment. In the Southern Indian Lake–Notigi Reservoir System, areas in which a large amount of mercury is held within the benthic community correlate with areas in which fish mercury burdens tend to be high. In areas where smaller amounts of mercury are held, fish mercury burdens tend to be lower.

Ancillary work stemming from this research involves an analysis of toxic stress by mercury on the chironomid communities in the different basins. Because of the range of mineral sediment interference created by erosion, the chironomid communities are exposed to a range of mercury contamination. Preliminary evidence shows that deformed chironomid larvae are present in samples from the lake-reservoir system, but at this date, analysis has not reached the point where any definitive statements can be made about the effects of mercury stress on chironomid communities.

Funding for the research on bioaccumulation processes was provided through the Canada Water Act under the Canada–Manitoba Mercury Agreement. (Warwick)

## EUTROPHICATION

**Phosphorus Dynamics.** Hypereutrophic lake conditions and nuisance algal blooms frequently make prairie lake waters unsuitable for municipal water supplies or for most recreational activities. The supply of plant nutrients feeding these blooms is difficult to control at the source. Naturally rich prairie soils, agricultural fertilization practices, and resuspension and recycling of nutrients already in the lakes are likely contributors to the algae problem.

In the present study, physical lake characteristics important to mixing and resuspension of bottom sediments in a large shallow prairie lake were examined to identify and quantify their importance in recycling nutrients in prairie lakes. The application of dynamic concepts to the movement of nutrients through lakes forms a complementary second step toward identification of parameters controlling nutrient availabilities. Accurate simulation of the dynamic flow of total phosphorus may allow rapid quantitative evaluation of engineering alternatives for phosphorus control on the prairie lakes.

A numerical model based on the principles of first order linear dynamics was developed to predict total phosphorus in lakes. The model was tested using published data from Lake Washington and showed that lakes respond as a forced system to changes in inflow phosphorus concentrations. It was concluded that the dynamics of total phosphorus in Lake Washington can be adequately represented by the use of two independent phosphorus sinks: the flushing of phosphorus from the lake through the outlet and the sedimentation to the lake bottom.

The theory of phosphorus dynamics was extended to describe the dynamics of total phosphorus in the upper four Qu'Appelle river-lakes (the Fishing Lakes). Although numerical simulation of total phosphorus was hampered by inadequacies in the quantity and quality of available data, the major trends were successfully modelled. The results suggest that the Fishing Lakes are saturated with phosphorus and no net sedimentation of phosphorus has occurred in the ten-year period for which data are available. This work clearly shows the importance of treating lakes as dynamic systems and has considerable potential for application to other locales. (Kenney)

**Palaeo-indices of Eutrophication.** Palaeo-reconstructions of eutrophication histories have proven valuable to management by presenting the development of eutrophication problems in the historical context. In many cases, however, the "reconstruction" is coloured by the indicator system used and different systems often provide seemingly different stories. This is particularly true of reconstructions based on sediment-borne (benthic) communities and waterborne (planktonic) communities. The purpose of this study was to compare the results provided by the two types of indicator communities and ascertain some of the reasons behind apparent discrepancies.

Sediment samples from the Glenora-B core from the Bay of Quinte, Lake Ontario, were provided to research teams headed by Drs. C.L. Schelske and E.F. Stoermer of the Great Lakes Research Institute, the University of Michigan at Ann Arbor, Michigan, for the measurement of biogenic silica and palaeo-diatom analyses. Warwick (1980) previously reconstructed the eutrophication history of the bay from the same core using subfossil chironomid remains as an indicator system.

Biogenic silica analyses showed that increasing inputs of phosphorus, correlated with cultural development in the bay area, led to the depletion of silica resources in the bay. The process was gradual and offset by silica inputs from tributary sources. In the last seven to eight decades, the pressure on silica resources by phosphorus-stimulated diatom growth became intense and led to silica depletion.

Analysis of subfossil diatom remains indicated that eutrophication of the Bay of Quinte occurred considerably earlier than predicted from subfossil chironomid remains. The discrepancy occurred during a period of rapid mineral sediment accumulation caused by widespread land clearing and erosion which, in turn, caused a period of "artificial oligotrophication" for the benthic community. Comparison of these studies shows that the response of bottom dwelling communities to trophic conditions is mediated by sedimentation processes as postulated by Warwick (1980) in the equation:

$$\begin{array}{l} \text{TROPHY} \\ \text{faunal} \\ \text{indices} \end{array} = \begin{array}{l} \text{TROPHY} \\ \text{productivity} \\ \text{indices} \end{array} - \begin{array}{l} \text{mineral sediment} \\ \text{accumulation} \end{array}$$

The correlations and comparisons have important ramifications on the interpretation of trophic conditions from contemporary and subfossil community structures. The results of the two studies are presented in Shelske *et al.* (1985) and in E.F. Stoermer, J.A. Wolin, C.L. Schelske and D.J. Conley, "Post-settlement diatom succession in the Bay of Quinte, Lake Ontario," *Can. J. Fish. Aquat. Sci.*, in press.

Research on the Glenora-C core, a companion core to the –B core, is being continued by Dr. B.J. Hahn, University of Manitoba, Winnipeg, Manitoba, using subfossil cladoceran remains as the indicator community. (Warwick)

## PRAIRIE LAKE PHYSICS

**Southern Indian Lake.** Residence time is a primary consideration in calculating chemical and nutrient budgets in aquatic ecosystems. Previous studies on the vertical temperature structure of Wupaw Bay, Southern Indian Lake, showed that the water column was inversely stratified under winter ice cover. The depth of the inverse thermocline varied monotonically along the length of the bay, with the most rapid change occurring in the channel connecting Wupaw Bay to Southern Indian Lake. Since this condition cannot exist in a static environment, the magnitude of the under-ice circulation was measured to determine its contribution to water, chemical and nutrient budgets.

Using prototype instrumentation, two different methods were employed to measure directly the associated under-ice current. Results indicate that frequency temperature fluctuations and mixing do occur in Wupaw Bay and the magnitude of the current is a significant factor in determining the under-ice residence time of water in the bay. Similar results are to be expected in other lakes and bays with similar morphometry. This work shows the importance of the winter period to redistribution of chemical and nutrient elements vital to the ecology of lakes. Consideration of the impact on the under-ice environment may be necessary for future development and diversion schemes in the North. (*Kenney*)

**Lake Manitoba.** Physical resuspension of bottom sediments during periods of high wind is thought to be important for nutrient recycling in large shallow lakes. Since conventional sampling techniques usually measure suspended sediments only at the top of the water column, a sampling device was designed to collect suspended sediment samples at closely spaced vertical intervals throughout the water column. The prototype was tested in the shallow southern basin of Lake Manitoba.

The device collected gram quantities of suspended sediment over periods of one month and successfully eliminated the fair weather bias that usually accompanies suspended sediment sampling in lakes. Chemical analyses suggest that resuspended sediment forms a large phosphorus pool which is potentially available to support blooms. Discontinuities in the vertical distribution of the dried mass of resuspended sediments and in the vertical distribution of particle size have important implications for lakewide circulation, the turbulence regime and for the long-range transport and redistribution of sediments in large, shallow lakes.

This device for sampling suspended sediments may have applications for collecting suspended sediments in rivers. (*Kenney*)

## STAFF LIST\*

A/Chief — Dr. B.C. Kenney

### Researchers

Dr. T.A. Jackson	metal biogeochemistry, nutrient geochemistry
Dr. E.D. Ongley	fluvial geomorphology, sedimentology
Dr. W.F. Warwick	paleolimnology, benthic biology

### Technical Staff

Ms. C.A. Casey  
Mr. J.C. Mollison  
Mr. K. Supeene  
Mr. J.P. Tisdale

\* Due to the Branch relocation to Saskatchewan, information with respect to degrees held by staff members was unavailable at the time of publication.

## PUBLICATIONS

Blachford, D.P., and E.D. Ongley. 1984. Biogeochemical pathways of phosphorus, heavy metals and organochlorine residues in the Bow and Oldman rivers, Alberta, 1980–1981. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 138.

Jackson, T.A. 1984. Mercury pollution in the Wabigoon–English–Winnipeg River system: Conclusion and recommendations based on results of the two-year joint study by the Governments of Canada and Ontario. In Mercury Pollution in the Wabigoon–English River System of Northwestern Ontario, and Possible Remedial Measures, Tech. Rep., pp. 383–388. Published by Government of Canada and Government of Ontario.

Jackson, T.A. 1984. Effects of inorganic cadmium, zinc, copper and mercury on methyl mercury production in Polluted Lake Sediments. In *Environmental Impacts of Smelters*, J.O. Nriagu (ed.), John Wiley & Sons, pp. 551–578.

Jackson, T.A. Mercury methylation in a polluted prairie river-lake system: Seasonal and regional variations and the role of trophic conditions. Submitted to Can. J. Fish. Aquat. Sci.

Jackson, T.A., J.W. Parks, P.D. Jones, R.N. Woychuk, J.A. Sutton, and J.D. Hollinger. 1984. Dissolved and suspended mercury species in the Wabigoon River (Ontario, Canada): Seasonal and regional variations. In Mercury Pollution in the Wabigoon–English River System of Northwestern Ontario, and Possible Remedial Measures, Tech. Rep., pp. 357–482. Published by Government of Canada and Government of Ontario.

Kenney, B.C. On the dynamics of phosphorus in lake systems. Environment Canada, Inland Waters Directorate, Sci. Ser. No. 144.

Kenney, B.C. 1985. Dynamics of phosphorus in a chain of lakes: The Fishing Lakes. NWRI, W&NR, unpub. rep., Winnipeg.

Kenney, B.C. 1985. Under-ice circulation in Wupaw Bay, Southern Indian Lake. NWRI, W&NR, unpub. rep., Winnipeg.

Kenney, B.C. 1985. Sediment resuspension and currents in Lake Manitoba. J. Great Lakes Res., 11(2): 85–96.

Ongley, E.D. 1984. Regionalization of water quality in the upper Fraser River Basin. British Columbia: Comment, Water Research, 18: 1059–1060.

Ongley, E.D. 1984. Review of Gregory (Ed.) Background to Palaeohydrology: A Perspective. Hydrol. Sci. J.

Ongley, E.D. 1984. The Saskatchewan River Basin Study: Nutrient and Contaminant Pathways in Prairie Rivers. NWRI – Western and Northern Region, Interim Report, October 5, Winnipeg, 19 pp.

Ongley, E.D. Detergent-phosphorus abatement: Point and nonpoint source basin response in southern Ontario. Environ. Geol. In press.

Ongley, E.D. 1985. Considerations for network design for water quantity and quality surveys in Canada. Canadian Hydrology Symposium - 84 – Proc. Laval University, Quebec City.

Ongley, E.D., and D.P. Blachford. 1984. Tributary effects on mainstream suspended sediment chemistry. Water Pollut. Res. J. Can., 19(1): 37–46.

Ongley, E.D., D.A. Birkholz, J. Carey, and M.R. Samoiloff. 1985. Occurrence and pathways of toxic chemicals in the North Saskatchewan River. NWRI Contribution 85–107, Winnipeg, 30 pp.

Schelske, C.L., D.J. Conley, and W.F. Warwick. 1985. Historical relationships between phosphorus loading and biogenic silica accumulation in Bay of Quinte sediments. Can. J. Fish. Aquat. Sci. 42(8): 1401–1409.

Warwick, W.F. 1985. Morphological abnormalities in Chironomidae (Diptera) larvae as measures of toxic stress in freshwater ecosystems: Indexing antennal deformities in *Chironomus* Meigen. Can. J. Fish. Aquat. Sci. 42(12): 1881–1914.

Warwick, W.F. 1985. Morphological deformities in Chironomidae (Diptera) larvae as biological indicators of toxic stress. In Proc. of the International Joint Commission Workshop on Persistent Toxic Substances and the Health of Aquatic Communities, June 18–21, 1985, Minneapolis, Minnesota.



## TECHNICAL OPERATIONS DIVISION

The Technical Operations Division is responsible for a variety of technical support to the field research projects of the Institute. Technical advice and assistance to other federal and provincial departments, agencies, universities and private industries is also provided when possible. Direct technical support was provided to over 70 NWRI studies in each of the last two field seasons including field measurement, sample collection and some analyses of physical, chemical and biological parameters.

The Division arranges for the acquisition and scheduling of research vessels, launches and land sites and coordinates all NWRI field research studies to ensure effective and efficient use of technical staff and materiel and financial resources.

Staff of the Division are responsible for a large inventory of field research-related equipment and provide for the preparation, modification and maintenance of a wide variety of mechanical, electronic and hydraulic sampling and data acquisition systems.

### SHIP SURVEY SECTION

Data gathering on the Great Lakes is accomplished using research vessels as sampling platforms. The Ship Survey Section coordinates the yearly scheduling of the vessels and provides logistics, equipment and technical support to all NWRI studies conducted aboard the three research vessels based at CCIW. The area of operations covered by these vessels during the course of the field season was from Duluth, Minnesota, through Lakes Superior, Huron, Erie and Ontario into the upper estuary of the St. Lawrence River, below Quebec City, Quebec.

**CSS *Limnos*** (Fig. 35). Thirty cruises were completed by the major research vessel *CSS Limnos* in 1984 and 23 during 1985 on Lakes Ontario, Erie, Huron, Superior and the St. Lawrence River. Detailed plans and reports were prepared for each cruise and are available from the Technical Operations Division upon request. A detailed overview of *CSS Limnos* activities can be found in the TOD Annual Activity Summaries for 1984/85 and 1985/86. The multi-disciplinary cruises involved the activities listed below.

**CSS *Bayfield***. Most of the work conducted by this ship was in support of Great Lakes Fisheries Research Branch programs. The ongoing Long-Term Biological Index Monitoring Program continued to collect chemical and biological data simultaneously at selected stations from Lake Ontario on a weekly basis. A total of 32 such cruises were carried out during 1984/85 and 24 cruises in 1985/86. Other work carried out by the *CSS Bayfield* included thermal bar studies, benthos sampling, *in situ* toxicity studies, and deployment and recovery of satellite-tracked drogues.

Microbiology samples were collected and processed weekly in support of the Analytical Methods Division study "Microbiology Responses." The two meteorological buoys located in Lake Ontario off the mouth of the Niagara River were monitored regularly.

**CSS *Advent*** (Fig. 36). During the 1984/85 field season, the *CSS Advent* completed cruises in support of NWRI studies. Eight cruises were conducted on Lake Erie – six in support of the Surveillance Continuity Study to provide historic data suitable for the detection of important changes in Lake Erie, one in

Location	1984/85	1985/86
Lake Ontario	<ul style="list-style-type: none"> <li>5 – Nutrient assessment studies</li> <li>5 – Lake Ontario moorings</li> <li>3 – Long-term bioindex</li> <li>3 – Persistent organic contaminants</li> <li>2 – Chemical forms and availability of phosphorus</li> <li>1 – Diurnal rhythms of planktonic iterations</li> <li>1 – Sediment trap moorings</li> <li>1 – Sediment homogeneity</li> </ul>	<ul style="list-style-type: none"> <li>5 – Open-lake surveillance</li> <li>3 – Persistent organic contaminants</li> <li>2 – Lake Ontario moorings</li> <li>2 – Long-term bioindex</li> <li>1 – Sediment homogeneity</li> </ul>
Lake Erie	<ul style="list-style-type: none"> <li>4 – Sediment and phosphorus resuspension</li> <li>2 – Chemical forms and availability of trace metals</li> <li>1 – Surveillance continuity</li> </ul>	<ul style="list-style-type: none"> <li>5 – Sediment and phosphorus resuspension</li> <li>1 – Sediment homogeneity</li> </ul>
Lake Huron/Georgian Bay	<ul style="list-style-type: none"> <li>1 – Open-lake surveillance</li> </ul>	<ul style="list-style-type: none"> <li>2 – Open-lake surveillance</li> </ul>
Lake St. Clair	<ul style="list-style-type: none"> <li>1 – Chemical forms and availability of phosphorus</li> </ul>	
Lake Superior		<ul style="list-style-type: none"> <li>1 – Open-lake surveillance</li> </ul>
St. Lawrence River		<ul style="list-style-type: none"> <li>1 – Organic and inorganic contaminants</li> </ul>





Figure 35. Installing sediment trap mooring from CSS *Limnos*.



Figure 36. Current meter deployment from CSS *Advent*.



Figure 37. T.O.D. rigger assembles tower from Lake St. Clair study.



Figure 38. MiniROVER underwater television camera.





Figure 39. NWRI W.A.V.E.S. tower in Lake Ontario.

support of Sediment and Phosphorus Resuspension and one in support of the Phosphorus Bioavailability Study. Eight cruises were conducted on Lake St. Clair. Seven of these were in support of the Plankton Dynamics Study for the Great Lakes Fisheries Research Branch to study the plankton ecology and dynamics of the lake as well as the impact of contaminants on nanoplankton and picoplankton dynamics; one cruise was conducted on Lake Huron, also in support of the Plankton Dynamics Study.

During the 1985/86 field season, cruises were completed in support of NWRI studies. One cruise was conducted on the St. Lawrence River on Chemical Forms and Potential Availability of Trace Metals which studied contaminants including toxic metal ions arising from sources in Lake Ontario and along the St. Lawrence River. Seven cruises were conducted on Lake Erie – five in support of the Surveillance Continuity Study, one in support of the Bioavailability of Phosphorus Study, and one in support of mooring retrieval with reference to loading from Lake St. Clair. A total of 11 cruises were conducted on Lake St. Clair. These cruises were to provide information on contaminant sources, sinks and historical loading patterns. These cruises also helped to develop a better understanding of factors and chemical properties that control environmental distributions. One cruise was conducted on the St. Clair River in support of the St. Clair River Contaminants Survey to determine the geographical extent of contaminants and localize possible industrial sources of contamination in a 5-km reach of the St. Clair River near Sarnia.

## FIELD SURVEYS SECTION

The Field Surveys Section coordinated and provided technical staff and equipment resources in support to NWRI field research studies throughout Canada and provided technical

advice, equipment loans and support to many Canadian and U.S. government departments, universities and private sector groups. The Section's four organizational units directly supported many shore and launch-based studies as well as providing on-site technical services such as rigging and diving shops, equipment storage and the NWRI video studio facility. Launches, small boats, field research sites, laboratory trailers, sampling equipment and vehicles were acquired and scheduled for field use. Staff were assigned to a wide variety of survey tasks and geographic locations.

**Rigging Unit** (Fig. 37). The rigging staff, shop, outdoor compounds and highbay warehouse facilities provided direct and indirect support to most NWRI field activities.

Services were provided at dockside for loading and unloading ships. Buoys, hardware, winches, generators, mooring arrays and other equipment were prepared for the field. Forklift, heavy-truck driving and trailer towing services were provided. Assistance in the field ranged from Saskatchewan to Prince Edward Island. Another major responsibility was the maintenance of NWRI's 25-unit vehicle fleet.

**Underwater Operations Unit** (Fig. 38). Responsibility was maintained for the safe conduct of all diving operations undertaken by all agencies of DOE and DFO staff at CCIW. The unit maintains close contact with the diving industry and holds a responsible position with the Departmental Committee for Diving Safety which determines and enforces diving policy. The Unit maintains and utilizes a large inventory of specialized research diving equipment, the most notable of which was the remotely operated underwater camera system which was successfully used during the St. Clair River Contaminant Survey. Dive support, training and equipment were provided throughout the past two fiscal years.



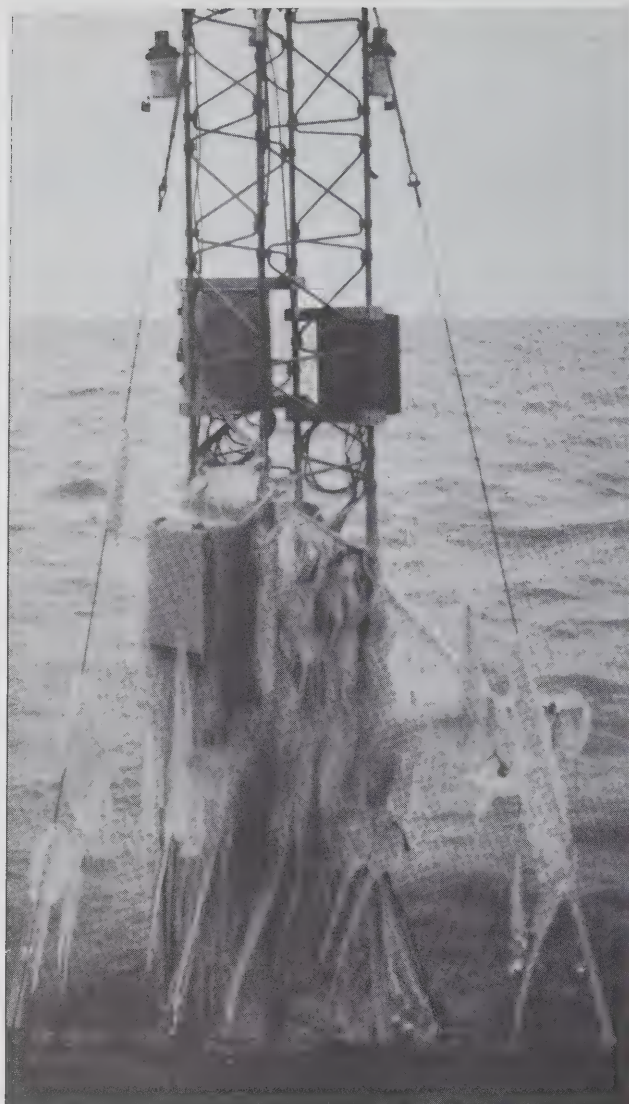


Figure 40. NWRI W.A.V.E.S. tower in Lake St. Clair.

**Field Stores Unit.** This unit maintained, issued and received a store of field sampling and support equipment. The inventory of over 500 line items was in constant use by field staff of NWRI and, as approved, by staff of the other components of CCIW. The scheduling and issue of five vehicles for short-term use by NWRI staff was also provided.

**Field Operations Unit** (Figs. 39, 40). During each of the fiscal years 1984/85 and 1985/86, support was provided to 50 NWRI studies and 15 additional requests from outside agencies. Detailed reports are available for all projects supported by the Unit. Staff supported field studies in all provinces and territories, and are trained and experienced in a wide variety of survey methodologies. The Unit conducted operations from small boats and launches, helicopters and fixed-wing aircraft and, during winter, over-ice operations were conducted using snowmobiles and all-terrain vehicles.

The Unit is also responsible for the maintenance and issue of all coring equipment for NWRI. Technical advice, training and equipment loans are regularly provided to other federal and provincial governments, universities and private industries.

## LIMNOLOGICAL INSTRUMENTATION SECTION

The instrumentation support group provides modification and maintenance of all shipboard electronic data acquisition systems. They are also responsible for the preparation and maintenance of current meters, temperature recording systems, meteorological recording systems, and electronic navigational devices. In fiscal year 1985/86, a major modification was performed. The existing shipboard EBT system was integrated to a transmissometer sensor head to form an EBT/Transmissometer system (EBT<sup>2</sup>). This system was used and field-tested during the latter part of the season.

### STAFF LIST

Chief — H.B. Macdonald  
Secretary — S. Mitchell  
Administrative Officer — C. Kennedy

#### Field Surveys Section

Head  
W.B. Taylor

#### Field Operations Unit

Head  
M.R. Mawhinney  
C. Bisutti  
T.J. Carew  
Y. Desjardins  
E.H. Walker  
G.D. Bruce

#### Field Stores Unit

W.D. Hunt

#### Rigging Unit, Head

L.J. Lomas  
H.E. Greencorn  
G.M. Perigo

#### Underwater Operations Unit

F.H. Don

#### Limnological Instrumentation Section, Head

J.A. Diaz

#### Current Meters and Data Abstraction

J.A. Tyler

#### Field Instruments and Meteorological Systems

E.G. Smith

#### Ship Survey Section, Head

P.M. Healey

#### CSS *Limnos*

B.H. Moore, O.I.C.  
L.E. Benner  
K.J. Hill  
J.A. Kraft, B.Sc.  
G.G. LaHaie  
J.E. Tozer

#### CSS *Bayfield*

P.R. Youakim, B.Sc., M.Sc.

#### CSS *Advent*

S.B. Smith  
R.J. Hess

## STAFF SERVICES DIVISION

Staff Services Division (SSD) is the lead agency for the provision of administrative, financial, property management, materiel management and records management services to all Environmental Conservation Service (ECS) elements, as well as those of the Environmental Protection Service (EPS), located at the Canada Centre for Inland Waters (CCIW). In addition, common support services are provided to those agencies of the Department of Fisheries and Oceans (DFO) and the Department of Supply and Services (DSS) located at CCIW.

### ADMINISTRATION SECTION

This Section is responsible for providing administrative and financial support to all NWRI Divisions. It also provides various administrative services to the Director, including the rollup of Institute Study Plans, Long-Term Operational Plans and Work Plans, and subsequent quarterly reports to HQ on the Work Plans. As well, it provides Institute-wide functions such as compiling the Conference Travel Plan; chairing the Contracts Review Committee, the CCIW Safety Committee, the CCIW Cafeteria Committee and membership to the IWD Information Technology Committee; providing information in accordance with the Access to Information legislation; preparing and analyzing monthly reports on the utilization of the Institute's person-year resources; liaising and coordinating all personnel-related activities with the DOE Burlington Personnel Office; devising and implementing office automation procedures; providing supervisory functions to all Wang users in ECS components at the CCIW; and coordinating the Canada Savings Bond Drive and the United Way Campaign.

This year a new contract was written for the word processing/ office information equipment, upgrading the central processing system to allow for scientific word processing, faster response time, and additional ports for an expected extension to the system.

A contract was let this year to provide work experience for two handicapped individuals. The original intent of the contract was to provide internal mail delivery service. However, this contract has been so successful that the two contract employees have been assigned other tasks, both inside and external to the Central Registry. As a result of this contract, CCIW has been awarded the "Employer of the Year Award" by the Ontario Association for the Mentally Handicapped.

This Section coordinated the CCIW Open House '85 held April 18–21, 1985. Approximately 30 000 people visited the Centre for what was clearly a most successful venture. Visitors were unanimous in their praise of the friendly reception they received and the quality of the exhibits.

A reference manual was written on the subject of Administrative, Financial and Materiel Management Procedures to provide the Pacific & Yukon and Western & Northern detachments with guidelines on how administrative and financial tasks would be carried out by the Burlington Office this fiscal year.

Visits were organized throughout the year for local public interest and educational groups. Of particular note was a visit

from the Bobingen, West Germany, School Band. A presentation of the CCIW Slide Show and tour of the Centre took place, which was facilitated by German-speaking NWRI staff accompanying the visitors.

The word processing shared resource centre provided support to four research divisions (AMD, APSD, AED and ECD) and the Director's Office staff as well as telecommunications support to the Institute and its detachments in Vancouver and Winnipeg.

The Safety and Security Unit of this Section provided St. John Ambulance first aid and Cardio Pulmonary Resuscitation training courses for staff members. Fire drills were held as well as testing of the emergency voice alarm system.

### BUILDING AND PROPERTY SERVICES SECTION

This Section is responsible for the physical operation and maintenance of the buildings, intrinsic equipment and the grounds, roadways and parking lots within the confines of the complex. It also provides technical assistance and advice concerning alterations, modifications or equipment installation for all on-site agencies. Finally, it is responsible for the telephone (voice and data) system throughout the complex.

Major projects this year include (1) installation of the new SL-1 voice and data system for all units in the complex; (2) installation of a new water disposal method resulting in major yearly recurring savings on sewage surcharges; and (3) implementation of several energy conservation initiatives that have drastically reduced power and water costs.

### MATERIEL MANAGEMENT SECTION

This Section is responsible for providing, on a day-to-day basis, procurement, inventory control and assets management, disposal, warehousing and stores and shipping/receiving services to all ECS agencies located at the CCIW. Highlights of this year's work include (1) implementation of the Automated Procurement Information System; (2) computerization of materiel receipts in the Warehouse Receiving Area, resulting in a more timely payment process in the Finance Section; and (3) automation of the NWRI inventory, enabling updating to the ECS Automated Inventory to be done through the Wang telecommunications mode.

### FINANCE SECTION

The Finance Section provides centralized computer accounting services for all ECS units at CCIW (NWRI, Inland Waters Directorate—Ontario Region, and the Water Quality National Laboratory). It also provides the accounting function for funds provided by the Regional Director General, Ontario Region, for the Great Lakes Water Quality Agreement. In addition, the Section is responsible for providing liaison between other government departments (federal, provincial and municipal) and suppliers with regard to payment of accounts





Mr. J.D. Smith accepts "Employer of the Year Award" from Mr. J.R. Brokenshire of the Ontario Association for the Mentally Handicapped. *Left to right:* Mrs. E. Rae, Supervisor, Mr. Philip Clark, J.D. Smith, J.R. Brokenshire, and Miss Susan Robertson.

and contracts. The Finance Section participates in the Institute's planning process by completing the annual rollup of Financial and Human Resource Plans and the Institute's Main Estimates.

### **LIBRARY SECTION**

This Section provides library services and facilities to all agencies located at the CCIW in support of their research and survey programs. In addition to the day-to-day functions, the following tasks were undertaken this year: (1) conducted a review of library services/operations by completion of a "User Satisfaction Analysis" and on-site visits to research libraries at Atmospheric Environment Service (Toronto) and Bedford Institute of Oceanography (Halifax) from which resulting recommendations were implemented to enhance the CCIW library services/operations and (2) maintenance and practice training sessions of the Library Disaster Plan. Since its inception, several government and private agencies have requested a copy of this plan.

### **CENTRAL REGISTRY SECTION**

Central Registry provides mail services to all in-house occupants as well as registry facilities for NWRI, Inland Waters Directorate—Ontario Region, and the National Water Quality

Laboratory. Telex, telecopier and photocopying services are provided for the Centre. This Section also provides an information service to other government departments and agencies and the general public, providing information on an informal basis or referring inquiries to the proper authority.

### **STAFF LIST**

**Chief — J.D. Smith, C.D.**  
**Secretary — H. Zrostek**  
**Administrative Officer — C. Kennedy**

#### **Administration Section**

F. Boyd, Administrative Officer, AED/ECD  
 C. Kennedy, Administrative Officer, SSD/TOD  
 J. Major, A/Administrative Officer, AMD/APSD  
 S. Hicks, A/Administrative Officer, HD  
 E. Jones, Word Processing Operator  
 A. Caswell, Word Processing Operator

#### **Building and Property Services**

**Head**  
**D.F. Stewart**

#### **Support Staff**

J.C. Stewart, C.D.



R.J. McCurdy  
G. Johnstone  
K.R. Taylor  
K. McCutcheon  
F. Adams  
A.K. Allaby  
A. Cruz  
J.P. Denomme  
W.A. Johnson  
T. Comiskey  
S. Wynne

**Materiel Management**

**Head**

**D.A. Burton, C.D.**

**Support Staff**

S.E. Hicks  
J.P. Mellon  
M.A. Eadie  
W. Coventry  
M. Ross

**Finance Section**

**Head**

**J.A. Jagoe**

**Support Staff**

Y.E. Hutton  
B. Titley  
E.A. Wendel  
D.G. Jefferson  
R.J. Haswell  
S. Westmoreland

**Library Section**

**Head**

**E. Dowie, B.A., B.L.S., M.L.S.**

**Support Staff**

P. Bennett  
K. Finch  
M. Sinclair  
E. McCallum

**Central Registry Section**

**Head**

**E. Rae**

**Support Staff**

M. Solvason  
J. Sims  
K. Cameron



















